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ART. I.—*On the Alternating Electric Arc between a Ball and Point;* by EDWARD L. NICHOLS.

[Contributions from the Physical Laboratory of Cornell University, No. 7.]

PART I.

(*From Experiments made by Messrs. W. K. Archbold, and G. L. Teeple.*)

THE phenomenon which forms the subject of this paper, was first brought to my notice by Mr. E. G. Acheson, the result of whose unpublished observation, may be briefly stated as follows:

Two wires, which formed the terminals of the secondary coil of an alternating-current transformer, were brought nearly into contact. One wire was armed with a ball, the other with a point. When the distance was such as to admit of a discharge between the two, it was found that a galvanometer in shunt around the ball and point, indicated a considerable flow of continuous current.

This phenomenon has recently been subjected to investigation by Messrs. Archbold and Teeple. Their experiments, from which in great measure, the data used in the first part of this paper have been taken, are described at length in their Thesis in Electrical Engineering, which is now in the library of Cornell University.*

The apparatus used in the verification of Mr. Acheson's observation, consisted of a Ruhmkorff coil of moderate size, the

* The Effect of placing a Ball and Point in a High Potential Alternating Current Circuit, by W. K. Archbold and G. L. Teeple. Thesis in MS., Cornell University Library; 1889.

interrupter and condenser of which had been thrown out of circuit. The primary coil, as in all instruments of that type, consisted of a few turns of heavy wire, surrounding a core of iron wires. When this coil was supplied with current from a small alternating-current dynamo, making 14000 reversals a minute, and the terminals of the secondary coil were brought into position, a discharge of considerable brilliancy took place between them. To the unaided eye, the discharge appeared to be perfectly continuous, but the fact that it was really of an intermittent and periodic character, was indicated by the emission of a well defined musical note, which corresponded in frequency with the period of alternation of the dynamo.

The terminals of the secondary coil were subsequently connected with a brass ball, about one centimeter in diameter, and with a point consisting of a steel sewing needle. These were mounted horizontally in well insulated bearings, the center of the ball in line with the axis of the needle. The distance between the ball and the point of the needle was capable of adjustment by means of a micrometer screw. A mirror galvanometer of two thousand ohms, having in its outer circuit about one hundred thousand ohms, was shunted around the ball and point (in parallel circuit with the air space between them). When the induction coil was put into operation, the ball and point being too far apart to admit of a visible discharge, the galvanometer needle remained at zero, but when they were brought within striking distance, a large and constant deflection was produced. When the ball and point were interchanged, the deflection was reversed, its direction always being that which would have resulted from a current flowing from the ball to the point. Under the influence of the discharge, which was intensely luminous, the steel needle was fused at the point and rapidly wasted by oxidation, so that it became necessary to find some more refractory material.* It was finally supplanted by a pointed platinum wire, which although rendered highly incandescent withstood the temperature of the arc much better than steel had done.

The following quotation will serve to indicate the conclusions reached by the observers in the course of their preliminary experiments with the platinum point:

* The attempt to use carbon terminals, led to the following observation. "A carbon pencil substituted for the point, gave the same effect, but upon putting the carbon in place of the ball, it still acted as a 'point.' If two carbons were used the more pointed one acted as a 'point.'—It was observed that the end of the needle was fused into a ball by the heat of the arc, and would then act as a 'ball' to the smaller particles of carbon projecting from the end of the pencil.—Two brass balls brought together, caused a drifting of the galvanometer needle from one side to the other, according, it is to be presumed, as the discharge changed the nature of the two surfaces, so that minute points formed on one or the other." (Archbold and Teeple; Thesis, p. 3.)

"The behavior of the arc, as its length is increased, is very curious. As the point is withdrawn the arc forms and sings with an even tone, the pitch corresponding to the number of alternations. The point becomes of a dull red color while the galvanometer gives a small but quite steady deflection. As the arc is drawn out it sings louder and more harshly, the point becomes redder, while the galvanometer deflection increases and becomes very unsteady. At a certain critical length the following phenomena suddenly occur: the tone becomes smooth and even, the point brightens almost to a white heat, the intensity depending upon the strength of the current, while the galvanometer deflection becomes much greater and very steady. The explanation suggested, and which subsequent experiments seem to confirm, is as follows: At first the arc forms both ways, the rapid succession giving the tone. As the arc lengthens the arc still forms from ball to point, but is only intermittent (occasional) from point to ball, giving the unsteady tone and deflection. Finally the distance becomes too great for the arc to form from the point to the ball, while it still passes freely the other way, and the tone and deflection become steady."*

It was to the conditions existing in the circuit when the critical length of the arc, above mentioned, had been reached, that Messrs. Archbold and Teeple chiefly devoted themselves. The limits between which it was necessary to maintain the arc, were exceedingly narrow, a very slight extension of the striking distance beyond the critical point, resulting in total extinction of the discharge. Small changes in the speed of the machine were sufficient to throw the apparatus out of adjustment, and the arc, once ruptured, would not reappear spontaneously. It could be re-established, however, by the momentary introduction of a bit of metal between the ball and point, or even by the interposition of a candle flame. The complete stability of the discharge was finally secured by driving the dynamo by means of a motor, the latter being supplied from a storage battery.

The main portion of the investigation consisted in the determination of the periodic changes of electromotive force and current during a complete cycle, when no arc existed, and of the modifications introduced into the curves of potential and current by the discharge between ball and point. Throughout the entire series of measurements, the striking distance was greater than the critical value already defined, a condition the maintenance of which was secured by watching the indications of the galvanometer.

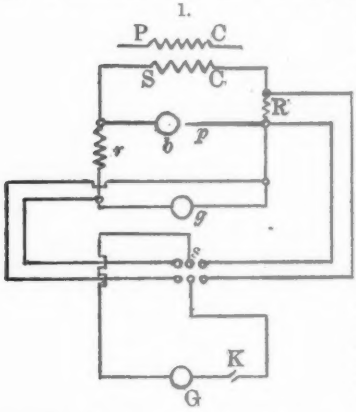
The instrument used in the measurement of electromotive force was a Thomson mirror galvanometer of ten thousand

* Archbold and Teeple; Thesis, p. 5.

ohms resistance. The galvanometer line was carried to the dynamo, where by means of an instantaneous contact device, the circuit was closed during an interval of exceedingly short duration, once in every revolution. The device consisted of a wooden disk, mounted upon the shaft of the machine. A single bar of brass, on the periphery of the disk, passed under a brush at every turn. This bar was connected metallically with a brass collar on the shaft, and a second brush, bearing upon the collar, completed the circuit. By thus closing the line through the galvanometer, for an instant, once in a revolution, the electromotive force of the secondary circuit, at that particular point of the cycle for which the contacts were made, could be measured; and since the brush was adjustable through considerable range, the entire cycle could be explored.

The arrangement of the entire apparatus is shown in figure 1. PC and SC are the primary and secondary coils of the inductorium, p and b are respectively the point and ball. R is a non-inductive resistance, g the indicating galvanometer, in parallel with the ball and point, r a non-inductive resistance, s a switch by means of which the Thomson galvanometer could be shunted at will around R or g. K is the instantaneous contact device, and G is the Thomson galvanometer. When the Thomson galvanometer was shunted around R, which was placed in the main circuit leading from the induction coil, it served to indicate the current flowing in that circuit during that portion of the cycle for which contact was being made; when connected in shunt with the galvanometer g, it measured the fall of potential through the coils of the latter instrument. The function of the indicating galvanometer, during this part of the investigation, consisted in showing, by the size and direction of its deflection, whether the discharge between the ball and point continued to maintain its proper character.

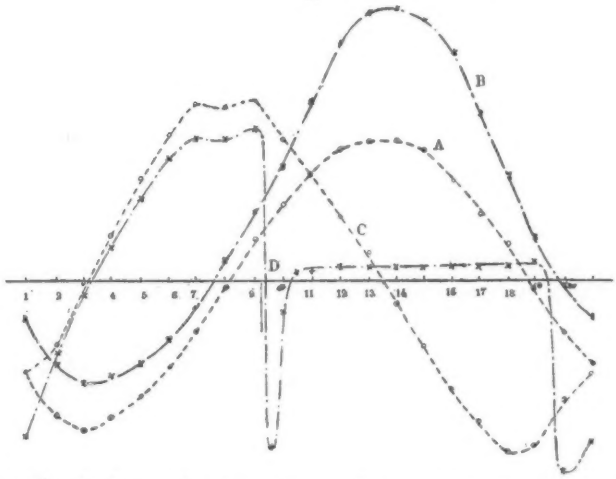
1.



The result of measurements throughout a complete cycle, both when the arc was formed and when it was extinguished, is shown in curves B and A, (figure 2). Curve A is with close approximation a curve of sines, and it indicates the usual fluctuations of current to be looked for in the secondary circuit of an alternating system. Curve B shows the current through-

out the cycle when the arc was playing. Abscissae represent portions of a complete cycle, the period being divided into twenty equal parts, ordinates the relative amounts of current through the resistance R, or the total current in the secondary circuit. Deflections, when the current flows from ball to point,

2.



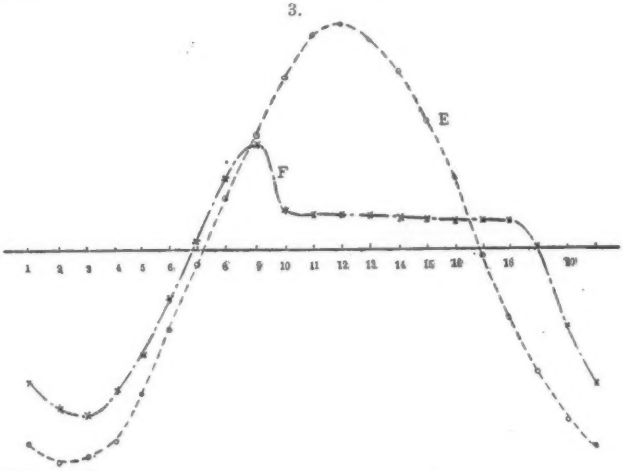
are plotted above the base line. As may be seen from the curve B, the current flowing in the positive direction during each cycle was greatly in excess of that flowing in the negative direction, when the discharge was taking place between ball and point, whereas when no arc was formed, (curve A) the areas enclosed by the positive and negative branches of the curve were equal. Now there were two paths offered to the current, that through the galvanometer, g and the resistance r, which consisted of a column of copper-sulphate solution between copper poles (approximately 112000 ohms), on the one hand, and the parallel circuit between the ball and point on the other. The resistance of the latter path was infinite whenever the arc was interrupted, falling to finite values during each discharge. Increase of current through R indicates, therefore, the formation of the arc. Such increase is found to exist during the second half of each cycle, that is to say, during that interval in which the ball is positive; and it might be inferred from these curves alone that the discharge was an intermittent one taking place always from ball to point. Other curves, taken simultaneously with A and B, the Thomson galvanometer being shunted around the indicator galvanometer, lead to the same conclusion. The curves marked C and D (figure 2), show the

results obtained. It was thought that they would give the fluctuations in electromotive force between ball and point, corresponding in time to the current fluctuations in the resistance R. The indicating galvanometer, however, owing to the very rapid alternations to which the circuit was subjected, was found to possess such high self-induction as to materially influence the result. Strictly speaking, the curves C and D, therefore, give the periodic changes of electromotive force at the terminals of the indicator and not those occurring at the ball and point.

These curves are nevertheless of considerable interest. The curve C shows the character of the cycle when no arc was formed, and D, when the arc was in operation; C, like A, is approximately a curve of sines. The irregularity at its positive crest, which also appears in D, is probably due to the imperfect performance of the contact brush, and having no bearing upon the phenomena which the curves are intended to elucidate, may be disregarded. Since no current was passing between the ball and point when A and C were taken, they represent the fluctuations in successive portions of the same circuit. The lag, due to self-induction, however, is very marked, amounting to almost 90° of phase. Curve D, which shows the influence of the arc, is especially instructive. The potential rises during the first part of the cycle (ball positive); then follows a very sharp oscillation, occupying about one-twentieth of the entire period or 1/4600 of a second of time. The potential then reaches a small positive value which it maintains without fluctuation for at least four-tenths of a complete cycle, when it suddenly becomes strongly negative.

To obtain curves of electromotive force between ball and point directly, a non-inductive resistance was substituted for the indicating galvanometer and the measurements from which curves C and D had been drawn were repeated. Of the two curves thus determined, the one taken when the arc was not playing (E, figure 3), is a sine curve closely coinciding in phase with the simultaneous curve of current (A, figure 2). The corresponding curve F, which was taken while the discharge was passing between the ball and point, is in its essential features of the same character as curve D (figure 2). The interval of uniform positive potential is of the same length and it is coincident with the interval of excess of current which shows itself in the positive branch of curve B. It is noteworthy that this interval of uniform potential, which marks the duration of the arc, occupies in both cases the same portion of the cycle, (between scale-divisions 10 and 19, approximately), although there is otherwise a difference of phase, due to self-induction, amounting to at least four scale divisions. Curve

C for instance, reaches its maximum in the neighborhood of scale-division 8, curve E at scale-division 12. The exclusion of the coils of the indicating galvanometer from the circuit, reduced this difference of phase to a small quantity, and it suppressed altogether the remarkable oscillation of electromotive force (see curve D) which in all preceding experiments had introduced the formation of the arc.



The results exhibited graphically in these six curves, afford abundant verification of the theory of the ball and point phenomenon, given in a previous paragraph; and they establish the fact that in the secondary circuit of a transformer, such as that made use of in these experiments, the striking distance from ball to point exceeds that from point to ball. It follows that whenever the space between the ball and point is less than the former and greater than the latter distance, discharge will occur only during that portion of each alternation for which the ball is positive, and that under such circumstances, a galvanometer placed in the circuit will show a constant deflection.

Complete corroboration of the foregoing conclusion, was obtained by studying the image of the arc in a revolving mirror. With a discharge of less than the critical length, the discharge was seen to consist of two distinct sets of sparks, all of the same duration but differing in color. Each alternate discharge was purple, the intermediate ones being of a greenish cast. The spark-images were everywhere equi-distant and their duration was about four times as great as the intervening intervals of darkness. The extension of the sparking distance beyond the critical point, resulted in the complete suppression of the

series of purple images, the intermediate ones remaining undisturbed in position, duration and appearance. The intervals of darkness were then estimated to occupy sixth-tenths of each cycle, the discharges, four-tenths; a ratio which corresponds with that of the duration of positive potential of the ball (as shown in curve) to the total length of a complete cycle.

The ball and point phenomenon is unquestionably very closely related to a class of effects with which students of static electricity have long been acquainted. One recalls, to begin with, Faraday's experiments with the Leyden jar; in which, of two paths, the spark invariably followed that involving passage from a positive ball to a negative point, in preference to another, through equal air-space, between a negative ball and a positive point.* Wiedemann and Rühlmann have since shown that between spherical electrodes which differ in diameter, the quantity of electricity necessary to produce a discharge is less when the larger ball is positive than when it is of negative charge,† and Macfarlane has measured the electromotive force which will produce a spark between a point and plate, and has found it to be greater when the point is positive than when it is negative.‡

In view of the experiments described in the present paper, it appears that what is true, in this particular, of the spark from the Leyden jar and the discharge of the Holtz machine, is true also of the alternating current arc.

Part II.

(From experiments made by Mr. F. C. Caldwell.)

After the completion of the experiments of Messrs. Archbold and Teeple, the study of the Ball and Point Phenomenon was taken up under the writer's direction by Mr. F. C. Caldwell; the chief purpose of the investigation being to test the applicability of the effect to alternate current measurement.§

Irregularities of action due to rapid changes in the surfaces of the point and ball, by corrosion and disintegration under the arc, finally caused the attempt to be abandoned, for the time being, but Mr. Caldwell in the course of his work, made a large number of observations of the discharge under various conditions. Many of these are of interest in this connection on account of the light which they throw upon the original experiments, and because of the lines of further research which they suggest.

* Faraday; Experimental Researches, § 1493.

† Wiedemann and Rühlmann: Annalen der Physik und Chemie, cxlv. See also Wiedemann; Elektricität, iv, p. 462.

‡ Alexander Macfarlane; Proceedings of the Royal Society of Edinburgh, vol. x, p. 555. 1879–80.

§ Frank Cary Caldwell: A study of the Alternating Arc between a Ball and Point. Thesis in MS. Library of Cornell University, 1890.

Mr. Caldwell's first step, after having repeated the preliminary experiments of Archbold and Teeple, and verified their statements, was to substitute a ball with a surface of platinum for the brass ball used by them. The new ball withstood the action of the arc no better than the old one had done. It soon became covered with a black deposit, the growth of which modified and vitiated the action of the apparatus. In experimenting with such a ball, the surface of which was still bright and new, and with a point of the same metal, it was noticed that within the critical distance, while the spark was passing in both directions, there appeared to be two distinct paths along which the discharge was taking place. One of these was nearly in the line from the point to the ball, normal to the surface of the latter, the other from the point in a direction approximately at 45° with the common axis of the pointed rod and ball. Upon increasing the distance until the discharge entered the "one way" stage, the longer and oblique path of flow vanished. In the revolving mirror the two classes of sparks were easily indentified. They were found to occur in alternation with each other, the spark which followed the normal path being that which passed from ball to point, the other that from point to ball. The images of the discharge from the point disappeared as soon as the critical distance was reached. In order to place the matter beyond all doubt, the times of the discharge which followed the normal path were determined by an ingenious method, quite independent of that used by the first observers, and it was found that the spark occurred always in that part of the cycle during which the ball was positive.

Mr. Caldwell's method of fixing the time of the discharge, briefly stated, was as follows. An adjustable contact device, similar to that used by Archbold and Teeple, was attached to the shaft of the dynamo. A wire from one pole of a large Holtz machine, driven by power, was carried to the neighborhood of the ball and point, where two platinum terminals, 1^{mm} apart were set up. The wire was connected with one of these and a line was carried from the other to the contact device. A wire from the latter to the remaining terminal of the Holtz machine completed the circuit. Whenever the brush made contact, a spark leaped between the platinum terminals, just described. By adjustment of the brush, the spark could be made to appear at any desired instant in the cycle of alternations of the dynamo. The platinum terminals were placed so that the image of the spark in the revolving mirror was seen side by side with that of the discharge between the ball and point, and the precise position in the cycle, occupied by the latter, was thus readily determined.

Closer study of the two paths of discharge showed that the oblique arc left the very apex of the point, swinging out later-

ally into its path; also that the normal arc on approaching the point, avoided the apex and entered the wire from the side, never passing in at the point itself.

From these observations it appears:

1. That the discharge from the ball (positive) leaves the latter in a direction normal to the surface, but that it enters the other terminal at some distance from the apex.

2. That the discharge from the point (positive) leaves the very apex of the latter, but is deflected into a course nearly 45° from the axis and reaches the ball obliquely at some point on its side.

Taking these observations into consideration, the explanation of the cessation of the discharge from the point at the critical distance and of the establishment of the "one way" arc, follows at once. The two paths of discharge differ in length and for a given electromotive force, the maximum striking distance is sooner reached in the case of the oblique than of the normal arc, so that the latter continues to pass at greater distances (of ball and point) than the former.

Further inspection of the images of the two arcs in the revolving mirror, revealed another curious fact. The mirror was set up with its axis of revolution parallel to the common axis of the ball and point. The image of an instantaneous spark following the line of the normal arc would therefore be a line parallel to the axis of the mirror. Since the duration of the discharge was nearly .001 seconds, this linear image was expanded into a broad rectangular band. The image of any oblique discharge would in general be an oblique parallelogram. The image of the discharge from point to ball, however, was not of that form. It appeared rather as a warped surface the form of which could be explained only by supposing that the discharge at first followed the normal path to the ball, and was gradually displaced as the cycle progressed, until it reached its extreme position at 45° to the axis, just before the rupture of the arc.

Definite results were obtained only while the platinum surface was new and bright. The region where the normal arc left the ball soon became tarnished and corroded and there was an increasing tendency on the part of the oblique arc to leave its own path and join the other.

When the ball was supplanted by a platinum wire, 1^{mm} in diameter, with rounded tip, the object being to force the two discharges into a common path, it was found that the arc from the point (positive) avoided the end of the wire altogether, and struck in upon the cylindrical surface beyond. When the end of this wire was surrounded by an insulated platinum ring which was connected with the terminal of the induction coil

by a separate wire,—the intention being if possible to separate the two phases of current and conduct them over different wires,—it was found that the arc from the point (positive) always entered the central wire, never being diverted to the ring, although the intervening air-space was less than a millimeter. The returning arc, however, would sometimes leave the ring and sometimes the wire, and a galvanometer placed in the circuit between the ring and the induction coil, showed a large deflection, such as would be caused by a flow of current towards the ring. This result seems to be in accordance with the conclusion reached from the inspection of the images in the revolving mirror: namely that the arc from the point always formed first along the shortest path. Deflection from that path in the case of the wire and ring, would probably be hindered by the insulating medium which intervened. When, finally, a cluster of points were opposed to the single point, it was found that the discharge from the latter was always along a single path, whereas the return arc from the cluster (positive) often followed several paths.

It had been noted by Messrs. Archbold and Teeple, that the platinum point used in their experiments, which was red hot while the arc was passing in both directions, became white hot during the "one way" stage. The heating effects at the surface of the brass ball were not discernible, but when Mr. Caldwell substituted a thin sheet of platinum for the ball, this became incandescent under the action of the arcs. The spot where the oblique arc (point positive) impinged upon the foil became white hot, while that at which the normal arc (ball positive) left the foil was barely red hot. In this respect then, the discharges act like the ordinary sparks of the influence machine or induction coil, which, as has been shown by Despretz, Poggendorf, Naccari and other observers, heat the negative electrode to a higher degree than the positive one. This action is in marked contradistinction to that of the continuous current arc, the positive terminal of which takes the higher temperature.

In this brief account of Mr. Caldwell's experiments, I have omitted to mention many of the observations recorded by him. He had occasion in the course of his investigation, to study the discharge under a variety of conditions, and found that when liquid surfaces (mercury or water) were used in place of the ball; also that when hydrogen, carbon-dioxide or illuminating gas were substituted for air, as a dielectric, the ball and point effect, more or less modified, could still be obtained. The investigation of these points, although it has already led to some results of significance, is as yet very incomplete.

Physical Laboratory of Cornell University:
September, 1890.

ART. II.—*Deformation of the Algonquin Beach, and Birth of Lake Huron;* by J. W. SPENCER.

FROM the ship's deck, my attention to the high terrace, which skirts the coast of Georgian Bay, was first attracted. But long before, fragments of this ancient shore-line were used by the Algonquin Indians, in the same manner as the Iroquois tribes had trailed over the "Ridge Roads" of Ontario and Erie. Mr. Sanford Flemming, C.E., described in 1853, some of the drift ridges at the head of Georgian Bay, and recognized certain high level beaches.* Later the Geological Survey of Canada measured the elevation of some of the raised terraces.† But those early investigators did not recognize either the extent of the beaches or their deformation from the water-level. No systematic explorations of the old shores were made until the summers of 1887 and 1888, when the writer, assisted by Professors W. W. Clendenin and W. J. Spillman surveyed portions of them. In the autumn of 1887, Mr. G. K. Gilbert visited some of the Canadian terraces. In August, 1888, I abruptly left the field and reported some results before the Cleveland meeting of the American Association for the Advancement of Science.‡ Some references to the Georgian Bay beaches were made in "The Iroquois Beach, etc.,"§ and later Mr. Gilbert generalized upon the history of the Upper Lakes, in an interesting paper entitled "The History of the Niagara River,"‖ wherein some of his raised shore-lines were taken from my survey, unpublished portions of which having been furnished to him.

Upon the Canadian side of the lakes, there are well preserved shore-lines, marking the same episodes, as those upon the American side, when all the lakes were covered by a common sheet of water (the Warren water). These raised beaches have been more or less surveyed, but they belong to an episode earlier than that recorded in the beach, which confined the waters to the Upper Lake basins not embracing that of Lake Erie. This beach, which skirted the head of Lake Huron, cutting off the waters from the Erie basin, is now submerged at its southern end, but it rises as a conspicuous feature in the

* Valley of Nottawasaga, Can., Jour. Toronto, vol. i, 1853.

† Geological Survey of Canada, 1863.

‡ "Notes on the Origin and History of the Great Lakes of North America," by J. W. Spencer, Proc. A. A. A. S., vol. xxxvii, 1888.

§ "The Iroquois Beach, a Chapter on the Geological History of Lake Ontario." Read before Phil. Soc. Wash., Jan. 1888, and Roy. Soc. Can., May, 1889. Proc. Phil. Soc. Wash., 1888. Trans. Roy. Soc. Can., 1889.

‖ Sixth Annual Report of the Commissioners of the State Reservation of Niagara for 1889.

topography of the country. I have named it after the Indians who, long ago, used it for a trail—the Algonquin Beach.* It forms the basis of this paper.

Between Lakes Huron, Ontario and Erie, at respective altitudes of 582, 573, and 247 feet above the sea, the land rises to 1709 feet. It shows water action to within 20 feet of its summit. From the highest ridges or plains, the land falls away towards the lakes, sometimes gradually, but often by abrupt steps, especially upon the northeastern side. Over this peninsula, there are many ridges of drift. Exclusive of the ridges, the general surface of the country is composed of fine stony till, or of modified drift,—the product of wave action upon the stony clay, the result of which has been the formation of beach ridges of sand and gravel, separated by plains of silt or clay soil. In many cases, these floors slope so gently as to appear level, and from two to five or six miles may intervene between successive beaches, whose altitudes do not differ by more than 50 or 60 feet. The silt on these plains is that which was washed out into the deeper water, by the assorting action of the waves that were building sand or gravel beaches in front of their coast lines, composed of the older stony clay. In such cases, the lithological recognition is striking. Upon surveying, the beaches are all found to rise in altitude toward the north and east, with a slightly increasing divergence between the ridges in the same direction, for the differential uplift has always been greater toward the northeast, than in the opposite direction.

The methods of investigation have been similar to those pursued in the survey of the Iroquois Beach. Boulder pavements are rather more important features of the Algonquin Beach than of the Iroquois. About the head of Georgian Bay the country is sandy. East of Georgian Bay, there is the same kind of broken wilderness as that among the Archæan rocks of the Adirondack Mountains of New York, with more or less stony sand in place of stony clay.

The waves of the lake are encroaching upon the eastern coast of Huron, and consequently modern beach-making is not a characteristic feature, except in proximity to the mouths of some streams or in sheltered places, where terraces or bars are constructed. The encroachments of the lake upon the land have washed away, in many places, the bluffs upon which the Algonquin Beach rests. But a sufficient number of fragments remain, for its identification, especially as the position relative to its elevation, compared with the next higher shore-lines, which are well marked by beaches, is known.

* The name was first printed in Proc. A. A. A. S., p. 199, 1888.

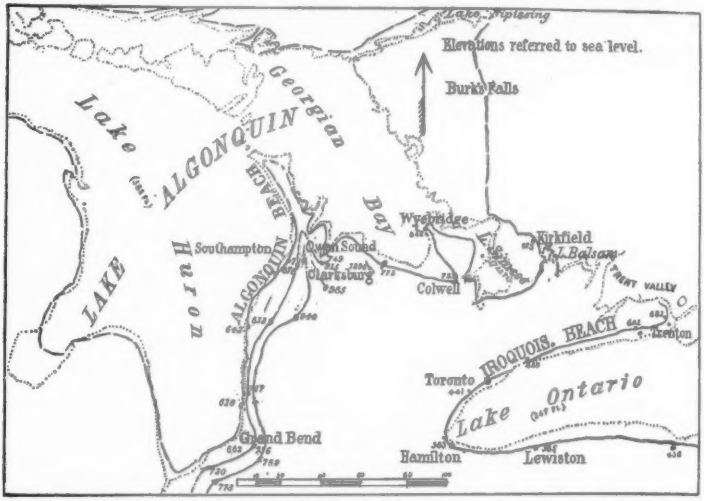


Fig. 1.—Map showing the Algonquin Beach about the eastern portion of Algonquin Lake. Other beaches are also shown.

The following table gives the levelled elevations of salient points along the Algonquin Beach, at or near the places mentioned:

	Feet above the Sea.	
Surface of Lake Huron	582	(U. S. Lake Survey.)
Beach at one or two miles lakeward of modern outlet of Lake Huron, calculated	562	(Spencer.)
Grand Bend (of Au Sable River)	602	"
Wilson's (14 miles northward, terrace at 608 feet, calculated)	618	"
Eighteen Mile Creek (terrace 637 feet, calculated)	647	(Barometer.)
Southampton (back of which a sand dune rises 13 feet higher)	714	(Spencer.)
Thence the beach skirts Indian Peninsula, and at Owen Sound	749	"
Clarksburg	773	"
Collingwood, 4 miles west of	767	"
Colwell	752	"
Elmsvale	802	"
Wyebridge, east of	842	"
Orillia, about	800	(Barometer.)
Thence the beach descends and swings around Lake Simcoe and again rises at Kirkfield	875	(Spencer.)
Burk's Falls (+ or −) (?)	1171	(N. W. & N. Ry.)

Beyond Kirkfield, the survey was not carried, but from the topography of the country and from the fragments of the beaches, the position of the Algonquin Beach is approximately that of the broken line on the map. The gravel ridge at Burk's Falls is probably part of the beach, as the mean rate of northern rise would represent its position near this point.

For comparison with the Algonquin Beach, the positions and the elevations of the two next higher beaches, east of Lake Huron are given on the map, and the tables of elevations are here added. Of next beach, at or near:

	Feet above the Sea.	
Forest	720	(Spencer.)
Parkhill, east of	736	"
Bayfield, east of	767	"
Ripley	813	"
Walkerton (terrace)	825	"
Paisley (terrace)	860	"
Burgoyne (east of Southampton)	876	"
Rockford, north of	915	"
North coast of Lake Simcoe (probably that) on the insular ridge north of Barrie	910	"

Of the second beach above the Algonquin, at or near:

Watford	773	"
Ailsa Craig	789	
Varna	845	(+)
Walkerton	944	
Chatsworth	985	

A still higher beach has been surveyed for many miles, and several fragments of even more elevated shores are now well identified. Some of these upper beaches have been traced over long distances, and have been found resting upon the land north of Lake Erie, and even extending to the high country between Lake Ontario and Georgian Bay.

From the figures recorded in the three tables, it will be found that the mean rate of warping in the Algonquin Beach, from the southern end of the lake to near Southampton, is 1·33 feet per mile; of the next beach, between Parkhill and Burgoyne, 1·5 feet; and of the higher beach, between Watford and Walkerton, 1·71 feet. These rates of differential uplift are reduced at their more southern extensions, but increased to two feet, or somewhat more, at the more northern.

After skirting the Indian Peninsula, the position of the Algonquin Beach surrounding the head of Georgian Bay is such that it can be triangulated, and hence the average amount of uplift, as well as its direction can be obtained. Accordingly, it is found that the uplift upon the more south-

western portion of the beach, at the head of the bay, is about 3 feet per mile, in a direction of N. 20° E., with an eastern equivalent of about one foot per mile. The uplift increases so that east of Georgian Bay the mean rise is 4·1 feet per mile in a direction of N. 25° E., with the eastern equivalent of 1·7 feet per mile.

At Grand Bend, the beach rests upon a fine stony drift clay—the latest deposit of till in that region—which is charged with numerous scratched stones. It is also indistinctly stratified. The same holds true at Wilson's and other places. About Georgian Bay, it also rests upon the upper till. In short, the waves, which formed the beach, have commonly removed the silt deposits that covered the floor of the lake, during the earlier episodes of the higher beaches, and cut into the underlying drift deposits during the Algonquin episode, before the beach structure was laid down. In many places, especially about Georgian Bay, the boulder-pavements are well developed, especially between the different ridges of the Algonquin Beach, for it is often broken up into a series of prominent ridgelets, the lowest being, where developed, as much as 28 feet below the upper.

There are several beaches about Georgian Bay, at lower altitudes than the Algonquin, but these rise less rapidly toward the northeast than the greater named beach. At Clarksburg, there is a beach at 81 feet above the lake, and terraces at 62 and 45 feet, besides a numerous series of beaches extending from 28 feet down to the water level. Near Wyebridge, the more conspicuous terraces are at about 183, 73, 55 and 11 feet above the lake; and there are numerous fainter shore-lines. These all show that the time of the subsiding of the waters was marked by numerous pauses.

Between Kirkville and Balsam Lake, there is a depression a few feet below the level of the upper part of the Algonquin Beach. But of this later.

No animal life has been found in the beach itself. But in a terrace, adjacent to the Saugeen River (bridge east of Southampton), where there is an embayment of the Algonquin Beach, there is a bed of fresh-water shells, discovered by Mr. Spillman. This is at an altitude of 90 feet above the lake, or over 40 below the beach. This deposit may have been on the floor of the lake during the Algonquin episode, or it may belong to a lower water-level. The river has now cut down its bed far below this level. At the head of Georgian Bay, fresh water shells have been found up to 78 feet.*

There are several depressions across the Laurentian Mountains, between Lake Huron and Hudson Bay which do not

* Geology of Canada, 1863.

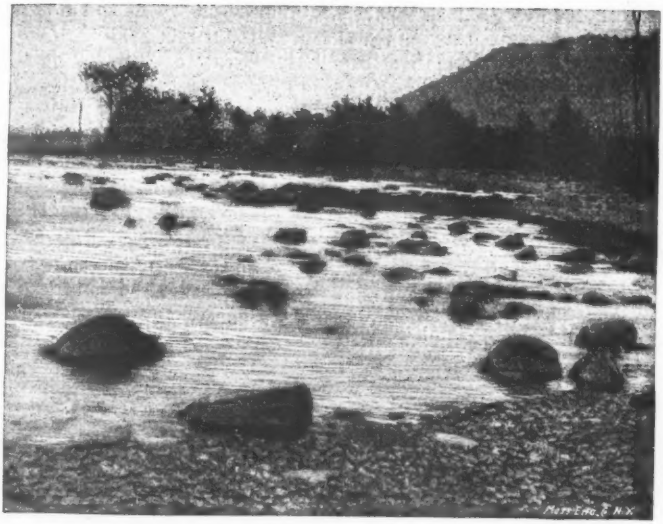


FIG 2.—MODERN BOULDER PAVEMENT ON GEORGIAN BAY,
NEAR THE END OF BLUE MOUNTAINS OF COLLINGWOOD, ONT.

FIG. 3.—ANCIENT BOULDER PAVEMENT OF ALGONQUIN BEACH.
(whose crest rises 187 feet above Georgian Bay) upon the N. E. side of Blue Mountains of Collingwood, Ont.

rise much more than 900 feet above the sea. But towards the northeast, the altitude of the land is everywhere high, except along the depression in which Lake Nipissing lies. The barrier there descends to 707 feet above the sea. Beaches and shore lines are known to exist upon the land north of the lakes, and I have seen such upon Manitoulin and Mackinac Island. But they have not been directly connected with the more southern beaches. Consequently, all deductions, in the study of the lake involving that district, must be somewhat provisional. From the character of the terrestrial rise increasing towards the east, it is probable that there are no depressions north of Lake Huron, lower than the plain of the Algonquin Beach. This beach (by calculation from the mean rate of rise) should be found in the vicinity of Lake Nipissing, at from 600 to 700 feet above that depression.

Combining the Canadian series of beaches about the upper lakes with corresponding series on the southern side of the lakes (my survey of those in Michigan being still unpublished), I find that there has been a differential elevation, since the Algonquin episode, between the southern end of Lake Michigan and the vicinity of Grand Bend, on Lake Huron, amounting to about 290 feet. Hence, we know that the Algonquin plain was down to a level, at least, of less than 300 feet above the sea. By a triple series of calculations, the Algonquin plain is found to have had a position somewhat less than 300 feet above the Iroquois plain. The Algonquin water filled the Huron basin to within a mile or two of its southern end, where the beach is now submerged to about 20 feet, (calculated). Hence, the waters did not flow by the modern St. Clair River to the south. At this time a considerable area of the southern end of Lake Michigan was laid dry, as the beach bounding the Algonquin water should now be submerged to 290 feet below the waters of that modern lake. But the northern part of the Michigan and Huron basins was filled to an elevation far above their present surface, as the basins had not yet received that great tilting which partly overflowed their southern margins and lowered their surfaces toward the north.

There is a well-marked terrace and beach deposit on Mackinac Island, at about 190 feet above the lake. This is nearly in the line of strike, or line along which there is no differential elevation, of the lowest part of Algonquin Beach about Georgian Bay. This old shore line, on the island, is better developed than any of the Huron Beaches, situated elsewhere, except the Algonquin. From its position, there seems no reason to doubt that the waters of Algonquin lake stood at that elevation in the strait between the Michigan and Huron basins. Accordingly, tilting in the Michigan basins has amounted,

since the Algonquin episode, to about 430 feet in 300 miles, or a little more. This approximation is close upon the mean rate of uplift measured east of Lake Huron. Parenthetically, it may be added that President Chamberlain found clays upon the western side of the lake which represent a differential uplift of 400 feet (although they belong to an older episode), which were in part involved in the earlier Pleistocene movements.

The Algonquin water also covered most of Lake Superior, probably to within a short distance of its southwestern end, as that basin is so deep; yet the waters must have been very much shallowed. Indeed, the recent backing of the waters towards the head of Lake Superior is apparent in the open bays behind the bars, which cut off Fond du Lac, at Duluth. The area of the Algonquin Lake or Water may be seen from what has been written, to have been vastly greater than now, filling the upper lake basins, nearly to their extreme margins, and overflowing the land northeast of Georgian Bay, as shown on the map. On Mackinac Island and adjacent portions of the mainland, there are several shore lines lower than that assigned to the Algonquin plain and of inferior importance.

In the early history of the Algonquin water, there was an overflow by way of Balsam Lake and the Trent valley. My first impressions of the importance of this outlet were overdrawn in the preliminary communication* of observations from the field, before all of the relations had been explored. At first I attached as much importance to the Balsam outlet of the Algonquin basin as Mr. Gilbert did to his Mohawk outlet of the Iroquois basin. As both are too shallow, the demands are satisfied in neither case. Only at its highest level did the Algonquin Lake overflow into Balsam Lake. Even the overflow was sluggish, permitting of the formation of beaches about the outlet. Before Algonquin water sank to the level of its lower beaches, its discharge was by a channel below Balsam outlet. The occurrence of an overflow in this last direction, is only one of the coincidences, as in other cases, in the growth of the lake. The outlet of the Algonquin Basin, by way of Lake Nipissing and the Ottawa valley, was through a depression, which now rises to 707 feet above tide. This trough has now an absolute depression of 168 feet below the Algonquin Beach at Kirkfield. But the altitude of the beach, in the region of the old Nipissing outlet, is estimated at 600–700 feet above its floor. In short the outlet was a broad strait leading into the Iroquois Basin, or like the modern connections between Lake Michigan, Lake Huron, and Georgian Bay, unless the basin were closed by a dam, and that of ice. The

* Proc. Am. Assoc. Adv. Sci., 1888, p. 197.

case is not settled so easily as that of the Ontario basin, for we have not yet the instrumentally measurable proof that the Algonquin plain was lower than 300 feet above the sea, although it probably was, and against which probabiltiy there is not the slightest evidence, for we do not know what was the initial plain of upward movement. Without applying the objections made to an ice dam closing the Ontario basin during the Iroquois episode, let us examine some conditions of the Algonquin basin.

The Algonquin plain stood at an elevation of about 300 feet above the sea, when the lower Iroquois Beach commenced its growth. Were its waters held up to that altitude by an ice dam, or had they shrunken to the lower level (which, however, would not have dismembered the upper lake) and were they connected with Lake Iroquois by a strait 300 or 400 feet deep, like the modern outlet of Lake Michigan? Up to this time, there had not been any warping to separate the lake basins, for the greater part of the barriers has been uplifted since the episodes of the Algonquin and Iroquois Beaches. I have shown that the greater proportion of the differential movement, even in the higher beaches about Lake Erie has been since the Iroquois episode.* In the earlier part of this paper, it has also been shown that most of the warping of the beaches, east of Lake Huron, has been since the Algonquin episode. Now these higher beaches are identical with those south of Lake Erie, whose movement have been compared with those of the Iroquois Beach. Hence, it is not difficult to understand that the unequal uplift of both the Algonquin and Iroquois plains has been nearly synchronous, since the completion of the latter beach. I speak only of the differential movements that have deformed the old water levels, and not of the absolute rise, which lifted the Algonquin plain above the Iroquois, unless the waters which made the former beach were retained at the higher altitude, for long ages, by an ice dam.

At most, no ice barrier could have longer blocked the Nipissing outlet than the episode of the lowering of the waters, 300 feet, to the level of the Iroquois Beach, for at that time, all glaciers had shrunken back beyond the Ontario basin, and the two basins were connected by the deep Nipissing Strait. And of such a dam we have not proof, or even probability, to even as great an extent as in the case of a hypothetical Iroquois dam. With the continued regional uplift, the waters of Algonquin Lake were further lowered, as is shown by the numerous beaches, until the lake was dismembered, and *Superior, Michigan, Huron and Georgia had their birth* and drained through

* "Deformation of the Iroquois Beach," etc. This Journal, vol. xl, page 443, 1890.

the last, at the level of the Nipissing outlet, only by a river flowing into the valley of the Ottawa.*

As we ascend to the elevation of the higher beaches, the question of glacial dams becomes more difficult, for we must assume them to have been hundreds of miles long and at enormous altitude, damming up bodies of water which had the proportions of inland seas. Such, I do not here propose to construct or dissipate, but I am compelled to assume the initial plain of the Algonquin Beach at sea-level, irrespective of glaciers which may then have been moving into the St. Lawrence valley, and obstructing open communication with the sea, but not damming the waters at high levels. There is as much evidence of submergence in these deserted beaches as there is in Professor Shaler's beaches † up to 1500 feet, on Mt. Desert Island, without the intervention of dams, or of Mr. McGee's Columbian formation‡ which I have seen in Alabama, at altitudes of about 700 feet without the support of dams. Indeed, there is additional evidence, for crustaceans of marine species have so adapted themselves as to still live in the depths of Lake Superior,§ as also maritime plants upon its shores.‖

As Algonquin water received so much fresh water, the marine conditions, indicated above, were modified, so that almost immediately after, if not during the formation of the Algonquin Beach, the waters became sweet, as is shown by shells referred to above. With the continued emergence and northeastward warping of the continent, a rocky barrier across the Nipissing outlet was raised which eventually caused the waters of Georgian, Huron, and Michigan Lakes to unite and overflow the southern extension of the lower beaches. Finally, this warping, as before pointed out,¶ so tilted the basins of the lakes that the waters overflowed the southern rim of the Huron basin, and established the modern drainage of the upper Lakes by way of Lake Erie. Not until this event did the lakes assume their present form.

* See History of the Niagara River, by G. K. Gilbert.

† Geology of Mount Desert, by N. S. Shaler. Eighth Annual Report of U. S. Geological Survey, 1888.

‡ By W. J. McGee. Bull. Geol. Soc. Am., vol. i, 1889.

§ "On the Deep-Water Fauna of Lake Michigan." (Stimpson) Am. Nat., vol. iv, p. 403, 1870; also "The Crustacea of the Fresh Waters of the United States." (Sidney I. Smith). Rep. Fish Commissioner, 1872–3, p. 643.

‖ "The Distribution of Maritime Plants in North America." (C. H. Hitchcock). Proc. A. A. A. S, 1870.

¶ Notes upon the Origin and History of the Great Lakes of North America, Proc. A. A. A. S., vol. xxxvii, p. 197, 1888.

ART. III.—*The Decimal System of Measures of the Seventeenth Century;* by Professor J. HOWARD GORE, B.S., Ph D.

JUNE 17, 1799, was a remarkable day in the history of the "Comission des Poids et Measures." After nearly nine years labor an arc of the meridian had been measured, the earth's quadrant had been computed, and now a bar whose length was one-ten-millionth of this quadrant, was formally presented to the two "conseils du corps Législatif." It is quite natural that the members of this commission should rejoice over the conclusion of their work, a work which readily sustained the closest scrutiny, and withstood the severest criticism, nor is it surprising that their spokesman should say: "to employ as a fundamental unit of all measures a type taken from Nature herself, a type as unalterable as the globe which we inhabit, to propose a metric system all of whose parts are intimately interdependent, and whose multiples and subdivisions follow a natural progression, simple, easy to comprehend, and always uniform, is certainly an idea, beautiful, grand, sublime, worthy of the brilliant century in which we live." In the detailed account of operations which follow, there is interspersed a large amount of praise for the participants—from Talleyrand, who laid the proposition before the Assembly on May 8, 1790, down to the laborers who carried in the prototype, on this august occasion. But one looks in vain for a mention even of the name of the humble, modest priest who deserves the credit of first proposing "a type taken from nature herself, as unalterable as the globe which we inhabit." This priest was Gabriel Mouton, of the collegiate church of St. Paul of Lyons. We shall see how well-known he was to his contemporaries and successors, and whether his system was borrowed by the advocates of the metric system, or was a subsequent independent discovery, after we shall have given an outline of his system.

	Milliare.	Stadia.	Funiculi.	Virgæ.	Virgulæ.	Digiti.	Grama.	Puncta.
Milliare	1	0	0	0	0	0	0	0
Stadium		1	0	0	0	0	0	0
Funiculus			1	0	0	0	0	0
Virga				1	0	0	0	0
Virgula					1	0	0	0
Digitus						1	0	0
Granum							1	0
Punctum								1

This scheme derived its unit from a *minute* of the arc of the largest circle that can be drawn around the world. A minute of arc was called a *milliare;* one-tenth of a milliare was to be called a *stadium;* one-tenth of a stadium, a *funiculus;* one-tenth of a funiculus, a *virga;* one-tenth of a virga, a *virgula;* one-tenth of a virgula, a *digitus;* one-tenth of a digitus, a *granum;* one-tenth of a granum, a *punctum;* as is conveniently exhibited in the following diagram:

If the above terms appear inconvenient to any one, the following were given so that one could take one's choice: Milliare, centuria, decuria, virga, virgula, decima, centesima, millesima. If we now take the accepted value for the quadrant in English measure, the various units will have these lengths in inches:

Milliare	72908·
Centuria	7290·8
Decuria	729·08
Virga	72·908
Virgula	7·2908
Decima	·7290
Centesima	·0729
Millesima	·0072

There were to be two units, the virga for large measures, and virgula for shorter ones—the former, about six feet, is most convenient for measuring those distances now expressed in yards, or meters, while the latter would be suited to those quantities now expressed as fractional parts of a foot, or feet. Those who use the metric system find that the meter is rather long for the latter class of quantities, nor is it convenient to use decimeter, and the jump to centimeter is too great, while for the first named measures the meter is too short. If these views be correct, Mouton's duplex units virga, and virgula are preferable to the meter.

Just when this scheme was proposed is not known, but it was prior to 1665, as some observations in connection with the fixing of his standards were made on the 8th of March of that year. Geodesy had not reached at this time a stage where its results could suggest their application to metrology; in fact only two determinations of the length of terrestrial degrees had been made, those of Snell and Riccioli, in 1617 and 1665 respectively. Not enough was then known of methods to enable one to judge as to the accuracy of either of these determinations, but Mouton says: Of all the observations I know of, ancient as well as modern, those of John Baptist Riccioli, which are described in the fifth geometrical book of the revised geography please me most, both on account of their wonderful harmony and the singular diligence which the above-mentioned

author has exhibited in treating of them, and also the industry and labor of twelve years, which he bore with an unwearied mind, for the sake of the truth that was to be attained. Indeed, I have such confidence in these observations, that I would regard my own, if I had any, as inferior to them; but hitherto I have been unable to accomplish anything in this subject, although I am very fond of such things. Mouton's estimate of Riccioli's work was far above its deserts, perhaps owing to the fact that they were friends and closely united by religious ties. An examination of Riccioli's arc measurement shows that his base was very short, that only two angles of each triangle were observed, that many of the angles were small, that some were determined indirectly as sums or differences of other angles, that no corrections were made for refraction and that some distances were estimated from meandered lines. Hence we are prepared for an erroneous result—62,650 toises for a degree. Snell's result was far superior, but was most likely unknown to Mouton—as the work published in Leyden would with difficulty reach Lyons, nor did the discussions of Munschenbroek and Cassini appear until many years after. So all the observations, ancient as well as modern, were represented on the modern side by those of Riccioli, Fernel and probably Norwood, as Picard had not at this time begun his labors. Our Metrologist went still further, not being satisfied with merely suggesting a system, he gave the length of his unit in terms of other measures. Riccioli gave his degree length in terms of the Bologna foot, and also in terms of the old Roman foot. This furnished Mouton a check as he had the ratio of the French foot to both; the two reductions were harmonious, justifying his belief that we cannot be ignorant of the true length of the virga and the virgula, which in comparison with the other geometrical measures are easily attained; and for the sake of this length, "we must test and observe many things, that will be not a little useful for the preservation of these measures." In reading this, one would hardly imagine that the pendulum principle discovered only a few years before this—though not published until eight years later, was referred to, and that Mouton had in mind the second's pendulum as the best means of preserving and transmitting his standard; yet this was the case, as we shall see from what follows: "A geometrical virgula is exactly equal to a pendulum which makes 2959·2 single vibrations in half an hour, as we shall show by means of many experiments, used for this purpose, through which we endeavor to show the length of the virga and virgula, a thing to be known by all others wishing to obtain it.

"In making use of the following and similar experiments, a very exact knowledge is required of the time that has elapsed. In order to obtain this knowledge more readily we must have recourse to the clocks of Christian Huygens, which are constructed with hanging weights. This Huygens was a remarkable man, of great learning, and one to whom posterity will always be largely indebted for his great assistance in mathematics. His clocks excel all others and correspond so nearly to the daily revolution of the sun that nothing more accurate can be hoped for. The fewer the wheels that are required in their construction, the more regular is their motion, but it is necessary for them to show the seconds as well as the minutes and hours, or if they fail to do this, we must count the single vibrations of a pendulum which will take place in a certain specified time. The motion of the pendulum, or the definite number of vibrations in a given time, when all outside resistance has been excluded, depends entirely upon its length, and if this varies very little, it must necessarily either increase or diminish the number of vibrations, and we prove by a common experiment that the squares of the numbers of vibrations of two pendulums that are equal in all respects except that of length, and vibrating the same length of time, are to each other in a reciprocal ratio as the lengths of the pendulums; and conversely the lengths of the pendulums are to each other in a reciprocal ratio, as the squares of the vibrations. I made a pendulum with a hemp string and an iron ball I divided the length—which may be anything—of the pendulum into 6772 equal parts, by means of an arbitrary division, for any number will do for the purpose, and nothing else is necessary except that the parts be very small. The length of the pendulum is the distance from the center of the sphere to the end of the thread. In this case the diameter of the ball was 160 of these parts, and the thickness of the thread almost 2 of the same. Having compared the aforesaid pendulum with the virga, the length of the virga was found to consist of 5397 of these parts. This being duly determined, I began counting the single vibrations of the pendulum, using two clocks with very fine weights, indicating seconds as well as minutes and hours. On the 8th of March, 1665, I counted different numbers of vibrations, corresponding to different periods of time, and repeated the operation about ten times. Upon the agreement of all these, the number of single vibrations in the space of half an hour was found to be $1117\frac{1}{2}$, which, applying the proportion already given, would show that a pendulum, the length of which is equal to a virga, makes 1251·8 single vibrations in half an hour." Subsequent observations gave for this quantity 1252, 1252·1, 1252·1, using pendulums of different

lengths and with balls of various sizes. The indiscriminate mean of these four series is $1252 \pm 0{\cdot}047$, a result which reflects great credit upon the observer. On the margin of a page is given the length of a virgula, with the naive confession that it is not given with such accuracy that we can take copies from it as if it were the standard—a remark made unnecessary by the careless trimming of the bookbinder.

The facts here established are: 1. Mouton devised a system of measure, arranged upon the scale of tens. 2. He derived his unit from the length of a minute of the terrestrial arc. 3. He showed how this unit could be expressed in terms of the seconds pendulum. It is now added, that this is the earliest decimal system proposed, that the French Academicians knew of this system, took from it its best features, and never gave credit where credit was due. Chronology shows it to be the earliest. As already stated, the two units, virga and virgula are more convenient lengths than the yard and foot, meter and decimeter; and so far as names are concerned, *decuria*, by tens, is as good as dekameter, while *decima*, the tenth part is better than decimeter. Again, the virga is an exact part of a minute, and is therefore an exact division of degree, quadrant and circumference, while the meter has *nine* degrees as its smallest exact multiple.

The only remaining point to be considered is: to what extent was Mouton known to his contemporaries and successors? As to the former it is impossible to even surmise.

His system forms pages 427–448 of his treatise "Observationes Diametrorum Solis et Lunæ . . . Una cum Nova Mensurarum Geometricarum Idea." Lugduni [Lyons] 1670. This small quarto was published with the "approval and permission of superiors," who, judging from the names appearing on the page which contains these approvals and consent, are the chairman of the Faculty of Paris, a Carmelite monk who announces that the book is orthodox, and a *Procureur du Roy*. This would give the book at least three readings before it was printed, and by men of such ability that they would appreciate the system proposed and discuss it with others.

Picard saw the book soon after its publication, nor did he soon forget it. This is shown in a report, published in vol. vii of the Memoirs of the Paris Acad., 1729, of observations made in 1672, 1673, and 1674. Picard, elated over the success which he had achieved in his geodetic work, sought new glory in making accurate astronomic observations at some of the principal cities of France. One of these places was Lyons, and while discussing his observations made when there he says: M. Mouton in his discussion of a universal measure, said that at Lyons a simple pendulum whose length was equal to a Paris

foot—a length given him by Auzout—made 2140·4 vibrations in half an hour, from which he concluded that the length of the seconds pendulum would be 36 inches 6·3 lines. That caused me to examine the matter very carefully while I was at Lyons, using for this purpose a large clock such as I had used elsewhere; and after all, I remained convinced that the true length of the second's pendulum at Lyons was 36 inches, 8·5 lines.

This application of the pendulum evidently pleased Picard, as in the same report he adds: if one had found the length of a seconds pendulum expressed in the usual measures of each country, one could know the relations of these measures as if they had been directly compared with one another,—besides this, one could detect at any time in the future a change in their lengths. These universal measures suppose that a change of locality produce no appreciable variation in the length of the pendulum; it is true that experiments have been made at London, Lyons, and Bologna, which seem to show that the pendulum shortens as the equator is approached, . . . but we are not sufficiently informed as to the accuracy of these observations to deduce any conclusions from them. Picard did not care to endorse the possibility of this shortening of the pendulum, it would have tended to corroborate the oblate spheroid hypothesis, which at this time was not at all popular at Paris. In 1733, Mouton sent to the Academy at Paris, a copy of the trigonometric tables which he had computed. In the note of acknowledgment, he is referred to as very well known by his work on the diameters of the sun and moon, and is called "habile dans les mathématiques."

As late as 1776 de la Condamine says: M. Mouton, priest at Lyons, was the first, whom I know, to propose a unit deducible from the pendulum; this was in 1670. He adds that it was proposed by Mouton in 1668 (it should be 1665), adopted by Picard in 1672, and by Huygens in the same year.

Cassini, in 1757, refers to Mouton as one whom we know only as a priest and master of the choir at the collegiate church of St. Paul. Perhaps this is simply to prevent people from supposing that his own scheme was not taken partly or wholly from Mouton. He proposed to take one six millionth part of a minute of a terrestrial arc and call it a foot. He also suggested that the unit be a toise, 60,000 toises being contained in a degree. This was simply taking one-thousandth of a minute, which was Mouton's identical plan.

Thus it is seen that Mouton's idea was never lost sight of. He was quoted often enough, and by such men as to keep his views from being forgotten, but when we come to that monumental work which recounts the incentives, beginnings, meth-

ods and results of the commission which deduced a standard of length, following a scheme proposed a hundred and thirty years before, and using a nomenclature too much like the former to be original, we seek in vain for a proper recognition of obligation and find in a few lines a mutilated account of Mouton's scheme, while he barely escapes condemnation in some words of faint praise from those who had thought of a universal measure. It is confidently believed that he who was known only as a priest and chorister was the originator of the decimal system of measures based upon geodetic data, and the brilliant century which deserves credit for the inception of a system which now promises to become universal was not the EIGHTEENTH but the SEVENTEENTH.

ART. IV.—*On the Clinton Oolitic Iron Ores;* by AUG. F. FOERSTE.

IN the Clinton Group districts of the Alleghany Mountains, the Clinton iron ores are often of the variety known as *Oolitic*. In making sections of these ores I discovered that the oolitic grains characterizing them frequently show the structure of bryozoans, and more evidently fragmental remains of the same. The grains, although rounded, have by no means the spherical character usually found in oolitic *concretions*, such for instance as occur in the so-called green sands of Cretaceous and Miocene age in this country. They evidently vary in size and shape with the character of the species from which they are formed, and with the size of the fragment before becoming waterworn.

As a rule the iron has replaced the substance of the bryozoan itself; all the stages between partial and complete replacement may be noticed, the most complete stages being of course found in the purer ores. Usually, corresponding changes are observed in the cement which binds the oolitic grains together into a solid mass. It is evident in these cases that the origin of the oolitic structure is not due to a concretionary segregation of iron particles, but finds its explanation in the gradual replacement of the lime of the fragmental fossil bryozoans, particle after particle, by the iron ore. When the bryozoans themselves have been replaced by iron ore, but the lime cement filling their original cell cavities has been but slightly altered, the sections of these grains under the microscope often present a very beautiful appearance.

At other times, especially in cases of bryozoan remains having cells of large size, the reverse is true, the lime of the bryozoans being little altered, while that of the cement once filling its cells, has been replaced by the iron ore. In this case

sections of the round iron ore grains are seen under the microscope to be divided into separate areas, between which the remains of the original bryozoans are still represented by calcite, showing their original cell structure. A beautiful case of this kind was collected by Dr. T. W. Harris, of Harvard University, from the Clinton oolitic iron ore, two miles below Rochester, New York, in the Genesee River, and kindly communicated to me.

The structures here described may, however, be observed over a much wider area. Microscopically valuable specimens were examined by me from the Clinton near Northumberland, Pennsylvania, and at Wildwood Station, Georgia. In fact these Clinton water-worn bryozoan remains are found throughout the Alleghany fields wherever Clinton oolitic iron ores occur.

Similar sections were also obtained from the Clinton oolitic iron ores at Todd's Fork, north of Wilmington, Ohio.

As might be expected from the foregoing remarks, both the bryozoan fragments and the cement filling their cells, since both are composed of calcite, are frequently replaced so completely by the iron ore that no traces of their original structure remains. All intermediate stages of alteration are of course present. In no case, however, was any thing noticed leading to the opinion that concretionary segregation of iron had taken place, either around the bryozoan fragments or otherwise. Simple replacement by iron ore was the rule, the attack being made first on the exterior parts of the grains.

The bryozoan fragments evidently belong to many species. It would be rash to attempt to identify the species, since the more fragile bryozoans of the Clinton Group have as yet received little study. The branching forms, as might be expected, are most largely represented. The most common are forms having cells arranged in radiating manner around an imaginary axis, but the bilateral Ptilodictydæ and Stictsporidæ are also represented. I see no reason for believing them to be other than good Clinton species.

It might be interesting to speculate as to what reduced these bryozoan remains to their present rounded forms. Of course this must have been due to currents in the Clinton ocean. But whether their presence is due to the waters of a *shallow* sea or not, and whether they indicate the proximity of *shore* conditions, I am not prepared to say. It will be pertinent, however, to state that the shores of the Clinton sea do not seem to have been far distant from the present metamorphic axis of the Alleghany system, and that the oolitic deposits mentioned from Ohio are found within 32 miles of the Clinton conglomerate at Belfast, Highland County, Ohio.

ART. V.—*Effects of Pressure on Ice;* by R. W. WOOD, JR.

CERTAIN theories regarding the movements of the great glaciers of the ice epoch, depending on the pressure-melting of ice, a number of experiments were performed by the writer, to determine the effect of great pressures on ice masses at various temperatures. The experiments were tried with a hydrostatic press capable of yielding a pressure of one hundred tons on its $6\frac{1}{2}$ inch ram, the first one being made to determine at what pressure ice could be made to flow through a tube of small diameter.

A block of iron was cast measuring $6\times4\times4$ inches, and drilled to the depth of four inches with an $1\frac{3}{8}$ inch hole, to which was fitted a solid steel piston, turned with such accuracy that, when oiled, it worked air-tight except under considerable pressure, when a few bubbles oozed through. Into the side of the block a $\frac{1}{12}$th inch hole was drilled, which communicated with the bottom of the cylindrical cavity precisely like the vent of a cannon. The cavity was nearly filled with ice at the melting point, and the steel piston inserted. The apparatus was then put under pressure: for a minute or two water flowed from the hole, with occasional air bubbles which effervesced with a white foam on emerging. The index of the guage showed that the ram was exerting a pressure of about six tons (three tons to the inch, the piston being two square inches in cross section) when the ice began to rise through the small hole. It rose slowly and steadily at first, as a cylinder of clear ice, which broke off when six or eight inches in height, then faster as the pressure increased, until the gauge indicated a pressure of nine tons, when it seemed fairly to spurt from the orifice, pieces two or three inches long being projected to a height of a foot or more into the air. It flowed with an irregular motion, which did not correspond with the strokes of the pump, but seemed to indicate that the ice was in a viscous condition, seeming to stick for a second or two and then yield suddenly. On reversing the press, and removing the piston, what was left of the ice was found moulded into a clear transparent block.

The next experiment was to test at what pressure ice at the melting point would become fluid as a mass. An iron block similar to the one used in the previous experiment, except that it was without the small hole, was filled with ice in which were imbedded several small bullets, the positions of which were carefully noted. The piston was fitted and the mass subjected to pressure. The index showed a tension of fourteen

tons, above which point it was difficult to force it, since the ice melted rapidly, and the water oozed out around the piston in spite of its perfect fit. On releasing the apparatus and removing the piston, the bullets were found in the same position; they had not dropped to the bottom of the cavity as they would have done had the mass been reduced to a liquid state, thus proving that under a pressure of seven tons to the inch (933 atmospheres) the ice had remained solid or viscous to such an extent that it could easily support the lead.

These same experiments were repeated under conditions of greater cold: the blocks, after being filled with ice, were exposed to a temperature of about $-5°$ Centigrade until thoroughly chilled, and were then carried to the press. This obviated the difficulty of the rapid melting caused by the heat of the iron. The results obtained, though practically the same, were more marked than in the first experiments. The ice cylinders came out with more violence than before, some fragments being projected to a height of ten or fifteen feet into the air. They were of clear, transparent ice and several inches in length. Small jets of water, in finely divided spray occasionally spurted out around the ice cylinders as they rose from the tube; this spray congealed on falling back upon the block, showing that the iron was below the freezing point.

The experiment with the bullets was repeated with the apparatus chilled below 0° C. A pressure of twenty-four tons was reached before the index of the gauge stopped; water spurted out in a spray around the piston, and instantly froze on the surface of the block as it ran down: ice, too, oozed out in thin sheets. On removing the apparatus it was found that the bullets had not dropped, showing that a pressure of twelve tons to the inch was insufficient to reduce the ice to a liquid state. One bullet which lay close to the wall of the cylinder had been ground between the piston and the wall, and a portion of it was spread out in a thin film over the iron. As a final test, a piece of oiled leather was inserted between the piston and the ice, which effectually prevented all leakage. The index hand moved slowly along until it reached a point indicating forty tons, when suddenly the air was filled with *fine jets of spray* which spurted in all directions from the block. The water had actually permeated the iron, forcing its way through the pores of the metal or breaking minute paths for its exit, and emerged in countless jets from the surface.

This of course put a stop to further experiments, the limit of resistance of the iron having been reached. A calculation will show that in the last experiment the pressure was sufficient to liquefy exactly one-fourth of the ice, being that produced by a column of ice twenty miles high.

Even under this enormous pressure the ice was found to have had sufficient viscosity to support the weight of the shot.

The maximum depth of the ice in the glacial epoch never exceeded two miles and such a mass would yield a pressure of about two tons to the inch, or two hundred and sixty-six (266) atmospheres. Sir William Thomson's experiments show that the melting point of ice is lowered .0075° C. for every atmosphere of pressure, that is to say, a mass of ice subjected to pressure has its temperature lowered .0075° C. for every additional fifteen pounds to the inch. Let us now consider exactly what the effect of a pressure of 266 atmospheres will be: the reduction of temperature will of course be $\cdot 0075° \times 266$, or − two degrees Centigrade (more exactly 1·955° C.). Starting with water at 0° we shall then have a mass of ice and water at a temperature of − two degrees Centigrade. To determine the amount of ice melted or reduced to a state of pressure-molten water, we make use of the well-known formula,

$$x = \frac{\text{temperature (in } -\text{degrees)}}{79 \cdot 25}$$

x being a fractional quantity representing the proportion of ice liquefied, and the constant quantity 79·25 being the latent heat of fusion for ice. The result is $\frac{1}{40}$, this being the exact amount of ice that will be liquefied by a pressure of 266 atmospheres. The condition of a lower layer of a mass of ice two miles thick will be as follows. The temperature will be −2° Centigrade, and a certain portion, namely $\frac{1}{40}$, will be in the state of pressure-molten water, which, being diffused through the mass of the ice, will not sensibly diminish its rigidity.

It will be seen that the pressure of such a mass of ice was considerably less than that required to cause ice at the melting point to flow easily and rapidly through a small orifice. It may be argued that the time element has not been considered. Time has nothing to do with the result, except as heat is fed to the bottom layer from the earth. Insulate the mass from all sources of heat, and the equilibrium will remain unchanged until the end of time. The law of conservation of energy decrees that this must be so.

It is true that glacial ice was not thus insulated: that it received heat from the earth we all admit, but let us consider exactly what the effect of this heat supply was. We have at the beginning a temperature of −2° C., and $\frac{1}{40}$ of the ice in a liquid state. Heat is fed from the earth which tends to raise the temperature, but the constant pressure keeps this uniform, and the heat is expended in melting more ice. After a lapse of time we shall have a considerable portion of the ice in a liquid state, but by considering carefully the conditions, we shall see that it is thermo-molten and not pressure-molten.

The temperature remaining constant, as it is bound to do under a constant pressure, we shall have a mass of water at −2° C. underlying a mass of ice of enormous weight. This water has not the properties necessary to prevent its escaping from beneath the ice, for if the pressure be relieved at a crack or break, only $\frac{1}{40}$ of the mass will congeal, which will scarcely be sufficient to seal the means of escape. In other words, as fast as water formed beneath the glacier, it would be squeezed out by the pressure of the ice. The results of these experiments appear to render questionable any theory accounting for peculiar motions of glacial ice by supposing the existence of a layer of pressure-molten water beneath the mass.

ART. VI.—*A Review of the Quaternary Era, with special reference to the Deposits of Flooded Rivers;* by WARREN UPHAM.

Two stages of great progress in knowledge of Quaternary geology were marked by the publication of the glacial theory by Louis Agassiz fifty years ago, and of "The Great Ice Age" by James Geikie sixteen years ago. And the degree of attention which deposits of this age are now receiving is even greater than ever before. Besides the vast mass of glacial literature which has appeared in the form of scientific papers in magazines and in reports of societies and of government surveys, two popular treatises have been recently published, summarizing what has been done in this field of geologic investigation in this country and in France and the western Alps.* The purpose of the present paper, based on my own observations and on study of the work of others, is to trace concisely the sequence of events during the Ice age and the post-glacial epoch, to discuss the probable causes of the great climatic changes of this era, and to notice especially its remarkable fluvial deposits.

The Quaternary era, according to definitions of recent textbooks of geology by Dana, Archibald Geikie, and Etheridge, began with the change from the mild Pliocene climate to that of the Glacial period, with its accumulation of vast sheets of land ice in high latitudes, and has continued to the present time. We are living in the Quaternary era, as thus defined, and it must extend far into the future to be at all proportionate in length with the previous co-ordinate divisions of geo-

* G. F. Wright, The Ice Age in North America, 1889. (Appleton & Co.) A. Falsan, La Période Glaciaire, 1889. (Felix Alcan, 108 Boulevard Saint-Germain, Paris.)

logic time. LeConte and Prestwich, however, consider the Quaternary division of time as completed at the dawn of civilization, with traditional and written history; and they assign recent geologic changes to a new era, which is separated from the preceding principally on account of the supremacy of man. The former view seems preferable, because man is known to have been contemporaneous with the Ice age, and it is therefore adopted in this article, the Quaternary history of our rivers being understood to include their formation and erosion of deposits through all their vicissitudes during and since the Glacial period.

By most writers the terms Pleistocene, Post-tertiary, and Post-pliocene, though etymologically applicable to the whole extent of time from the Pliocene till now, are used restrictively as synonymous with the Glacial period, embracing its stages of beginning, of alternating glacial and interglacial epochs, and of final recession of the later ice-sheets, to which closing stage of Glacial or Pleistocene time the name Champlain period has been given by Hitchcock and Dana, from the marine beds then deposited in the basins of Lake Champlain and of the Saint Lawrence and Ottawa rivers. Investigations of the Quaternary geology of the United States by McGee, Chamberlin, Gilbert, Russell, and others, have shown that the Glacial period or Ice age was complex, comprising in this latitude three principal epochs, namely, the first glacial epoch, with minor oscillations of the boundary of the ice-sheet upon the northern United States, culminating in its maximum southward extension to Cincinnati, Saint Louis, and Topeka, but leaving a large tract unglaciated in southwestern Wisconsin and the edges of adjoining states; then, a long interglacial epoch, in which the ice-sheet was melted back far to the north, or indeed quite probably may have wholly disappeared from this continent, while many of our rivers eroded deep channels through the bed-rocks, leaving here and there high terraces and deserted portions of the courses which they had occupied during the earlier glaciation; and, lastly, the second glacial epoch, when again ice was accumulated in great thickness upon the country, reaching south to Nantucket, Martha's Vineyard, Long Island and Staten Island, and into northern New Jersey and northern Pennsylvania, throughout this distance attaining at least as great extension as the earlier ice-sheet, but farther westward across the Mississippi basin falling short of the early glacial boundary by a width that varies from a few miles to about 275 miles. Both the growth and departure of the later ice-sheet, and also of the earlier, appear to have been marked by irregular stages of advance, retreat, and re-advance, many times repeated, as shown by vegetal deposits, as trunks and

branches of trees, layers of peat, or patches of the old surface soil, enclosed between deposits of the till or unmodified glacial drift, and by numerous roughly parallel and interlocking belts of hilly and knolly drift, amassed as terminal moraines at the margin of the ice during its interrupted and oscillating final retreat.

Extensive and thick beds of gravel, sand, and clay or fine silt, called stratified or modified drift, were deposited in valleys which received the drainage from the glacial melting, especially during its comparatively rapid progress in the Champlain period. The dissolution of the ice, with accompanying rains, produced extraordinary floods along all the rivers flowing away from the waning ice-sheet; and these were heavily laden with detritus set free from the ice in which it had been held, and brought down by the rills and small and large streams formed on the melting ice surface. Other portions of the englacial drift were let down as till in a loose unstratified mass upon the subglacial till or ground moraine, making the Champlain epoch, as Professor Dana has shown, preëminently one of abundant deposition, both of stratified and unstratified drift.

This epoch was immediately succeeded by one of rapid erosion of the valley deposits, as soon as the continued glacial recession beyond the drainage areas of the rivers cut off the supply of water and of drift that had been derived from the melting ice. The resulting excavation of the glacial flood-plains has left remnants of those deposits in conspicuous terraces along all our river valleys which lead southward within the glaciated region or on its southern border; and postglacial time, extending to the present day, is therefore named by Dana the Recent or Terrace period. It is to be remarked, however, that much of the terracing of the valley drift was doubtless done speedily after the retreat of the ice from any basin, while yet adjacent drainage areas on the north were receiving from it thick flood-plain deposits. The Glacial, Champlain, and Terrace periods thus overlap, the second being wholly, and the third partially included within the Glacial or Pleistocene period, if continental areas are considered; but for any limited district, as a single river basin, the sculpturing of the terraces took place chiefly after the departure of the ice beyond its water-shed.

Deposition and erosion by rivers are determined by their rate of descent, their volume, and the amount of detritus which they hold in suspension, received along the higher portions of their course. All these conditions have been subject to important changes during the Quaternary era, not only for the regions that became ice-covered in the Glacial period, but also for many other parts of the earth's surface. The efficiency of

the rivers in erosion, transportation, and deposition has been often increased by these changes, with the result that abundant fluvial deposits have been spread upon the land, along the valleys and in great alluvial plains. At the same time an immense tribute of river silt has been borne forward to the sea and forms a part of the submerged margins of the continental plateaus. If the proportion of the deposits made by the rivers before reaching the sea appears to be greater than in previous eras, the contrast is probably attributable to the more general preservation of marine than of fresh-water formations, the latter being liable to repeated erosion until they finally are carried beneath the level of the ocean.

Foremost among the Quaternary changes affecting river action have been oscillations of the land, both of continental areas and of mountain ranges. Fiords and submerged valleys indicate that the glaciated areas of North America and Europe have been elevated 2,500 to 3,000 feet above their present level. The district intersected by the Grand Cañon of the Colorado has been uplifted, according to Powell and Dutton, not less than 6,000 feet, causing the river to erode to this depth, during Pliocene and Quaternary time; and the latest comparatively rapid elevation, amounting to about 3,000 feet, the depth of the inner or lower part of the cañon, is referred to the early Quaternary. In this epoch, also, great uplifts and subsidences by faulting have taken place, as shown by Powell, LeConte, and Diller, in the Great Basin region, with its monoclinal mountain ranges consisting of blocks of faulted but not usually flexed or folded strata; while the lofty Sierra Nevada has the same structure, and attained its present prominence at the beginning of the Quaternary era. In South America the observations of Alexander Agassiz show that the Peruvian Andes have experienced Quaternary uplifts of 2,900 feet, or perhaps much more; and Medlicott, Blanford, and other explorers find that much of the mountain-building of the Himalayan range, and the formation of the table-land of Thibet, belong to the same latest era of geologic time, and that large tracts of central and northwestern Asia have contemporaneously risen out of the sea. These upward movements, generally followed in glaciated regions by depression while the land was ice-covered, but mainly permanent or only partly counteracted by subsequent sinking in the mountain ranges, have given to the rivers temporarily or permanently steep gradients and consequent increase of power to erode and transport material, which has been often deposited in very extensive gently sloping plains along their lower courses, on account of the decrease there in the rate of their descent and the slackening of their velocity.

Before considering these river deposits, however, we shall need to inquire somewhat more in detail what movements of elevation and subsidence have affected our own continent, and what have been the influences of Quaternary climatic conditions, and of the ice-sheets, upon the volume of our rivers and upon the supply of detritus which they have transported.

The evidences of great uplift of North America preceding the Pleistocene period have been impressively stated by Prof. J. W. Spencer.* The submarine border of the continent is cut by valleys or channels, which are doubtless river-courses that were eroded while the land stood higher than now; and its subsidence evidently took place in a late geologic period, else these channels would have become filled with sediments. According to the United States Coast Survey charts, as noted by Spencer, the bottom of such a submerged valley just outside the delta of the Mississippi is found by soundings at the depth of 3,000 feet. The continuation of the Hudson River valley has been traced by detailed hydrographic surveys to the edge of the steep continental slope, at a distance of about 105 miles from Sandy Hook. Its outermost twenty-five miles are a submarine fiord three miles wide and from 900 to 2,250 feet in vertical depth, measured from the crests of its banks, which with the adjacent flat area decline from 300 to 600 feet below the present sea level.† Again, the Coast Survey and British Admiralty charts, as Spencer states, record submerged fiord outlets from the Gulf of Maine, the Gulf of Saint Lawrence and Hudson Bay, respectively at depths of 2,664 feet, 3,666 feet and 2,040 feet. In California, too, Prof. George Davidson, also cited by Spencer, reports three submarine valleys about twenty-five, twelve, and six miles south of Cape Mendocino, sinking respectively to 2,400, 3,120 and 2,700 feet below the sea level where they cross the 100 fathom line of the marginal plateau.

Preglacial elevation of this continent is further attested, but without supplying measurements, like the foregoing, of its great extent, by the eroded areas of Pamlico and Albemarle sounds, and of Chesapeake and Delaware Bays; by the fiords of Maine, of all the coast northward to the Arctic regions, and of the Pacific Coast south to Vancouver Island and the Columbia River; by the Golden Gate, which has a maximum depth of 414 feet; and by the islands south of Santa Barbara and Los Angeles, which were united with the mainland during the later Pliocene and early Quaternary periods, as Pro-

* Bulletin, Geol. Soc. of America, vol. i, 1889, pp. 65–70; also, Geol. Magazine, III, vol. vii, pp. 208–213, May, 1890.

† See Prof. J. D. Dana's recent discussion of the submarine Hudson river channel, with map reduced from a chart of the U. S. Coast Survey, this Journal, III, vol. xl, pp. 425–437, Dec. 1890.

fessor LeConte has shown, whereas now they are separated from the mainland and from each other by channels twenty to thirty miles wide and 600 to 1,000 feet deep.

The general absence of marine Pliocene formations in North America and northern Europe indicates that the areas on which ice-sheets were accumulated in the Glacial period had long stood higher than now; and this elevation probably was shared, in its culmination, by our entire area north of the Gulf of Mexico, including even our southeast coast from the Carolinas to Florida, where scanty Pliocene beds are found. The altitude attained by this continent was about 3,000 to 3,500 feet, if not more, above its present level, as is known by the valleys that were then eroded on the margin of the continental plateau but are now submerged. The greatest height seems to have been reached in the early part of the Quaternary era, causing snowfall to prevail, instead of rain, throughout nearly the whole year in what are now temperate latitudes, and thus inaugurating the Ice age. South of the glaciated area, the Allegheny Mountains and all the southern part of the United States received increased precipitation of snow in winter, but it was melted by the warmth and rains of summer.

If this view is true, that the great elevation of the land was the principal cause of its glaciation, the height must have been maintained during a considerable time, sufficient for the accumulation of thousands of feet of ice; and after an interval of subsidence, at least for the southern part of the region, marked by the interglacial epoch, we must suppose that another uplift brought on the later ice-sheet. But the whole extent of the time during which the land was held at great heights by the successive uplifts could only have been a small part of the Quaternary era; for such elevation would evidently afford as favorable opportunity for erosion by the rivers in their steep descent on the margin of the continental plateau as has been granted to the Colorado River in the erosion of its Grand Cañon. We may therefore infer that the combined length of the Glacial epochs bears somewhat the same ratio to the entire Quaternary era as the extent of the short submarine fiord of the Hudson bears to that of the long and more profound inner cañon of the Colorado.

The uplift of North America in late Tertiary time brought to the partially or almost wholly base-levelled basins of rivers on the Atlantic slope and in the central United States a new cycle of erosion, as Davis and Wood have shown in northern New Jersey,* and President Chamberlin for the Upper Mississippi and its tributaries.† Tertiary erosion, probably most

* Proceedings, Boston Society of Natural History, vol. xxiv, 1889, pp. 393, 412.

† U. S. Geol. Survey, Sixth Annual Report, pp. 222–4. Geology of Wisconsin, vol. i, p. 255.

active during the Pliocene period, has produced the main features of the present valleys of the Mississippi and Ohio Rivers; and in the latter the smoothly flowing outlines and moderate slopes of the surface shaped by this erosion present a remarkable contrast with the steeper sides of the inner or lower part eroded during Quaternary time.

The highest gravel terraces of the Ohio are found at the line thus dividing the Tertiary and Quaternary erosion, and these terraces contain material supplied from the drift of the first Glacial epoch.* The ice-sheet of this epoch stretched south to the northern tributaries of the Ohio, and even crossed this river at Cincinnati, probably damming back its waters for some short time, and perhaps repeatedly, to form a lake along the Ohio to Pittsburgh and far beyond up the confluent Allegheny and Monongahela valleys. A glacial dam could exist, however, only at the stage of maximum advance of the ice, and its short duration permitted little record in terrace or delta deposits. The high terraces before noticed are of fluvial formation, apparently belonging chiefly to the time of the recession of the earlier ice-sheet, when the floods supplied by its melting were discharged along this valley, bringing part of its englacial drift and laying it down as a gently sloping fluvial plain of gravel, sand and silt.

On the Ohio, Allegheny, Susquehanna and Delaware Rivers, below their highest terraces and scanty remnants of the flood-plains of the first Glacial epoch, Chamberlin and McGee find that interglacial erosion deepened the valleys 200 to 300 feet through the hard bed-rocks before the epoch of the later glaciation.† The drift of this second Glacial epoch is distinguished from that of the first, which has a greater extent in the Mississippi basin, by terminal moraines formed on the extreme boundary of the later ice-incursion and at successive stages of halt or re-advance of the ice-sheet during its departure. A long interglacial epoch, as measured by years, must have divided the epochs of glaciation, and its cause was probably a considerable subsidence of the continent, or at least of the eastern United States and the Mississippi basin, but apparently not to the sea level. That there was greater altitude, and probably more descent from north to south during the interglacial epoch than during the Tertiary erosion, is indicated by the narrowness and steep sides of the Quaternary portion of these valleys.

From the observations thus made in valleys tributary to the Atlantic ocean and the Gulf of Mexico, the earliest Quaternary record for the northern part of that area appears to be the

* Chamberlin and Wright, Bulletin No. 58, U. S. Geol. Survey.
† Bulletin Geol. Soc. of America, vol. i, pp. 472–4.

envelopment of the land with an ice-sheet, which extended on the Ohio and the Mississippi to the extreme southern limit of the till and glacial striæ. But in the Great Basin and Sierra Nevada region early Quaternary events, according to LeConte and Diller, were the formation of immense faults, by which the mountain ranges were upheaved, the turning aside of rivers from their former courses, and the outpouring of lavas, which are often found capping the old auriferous river gravels.* In the long interglacial epoch of the northeastern area, the Sierra Nevada and Great Basin ranges were undergoing erosion at a far more rapid rate than the valleys of the eastern rivers; and to this time we must assign the accumulation of the greater part of the very thick alluvial deposits of the arid region, which are called "adobe" and compared with the loess of China by Russell.

The ensuing second Glacial epoch, with a southward advance of the ice on the Atlantic coast beyond that of the earlier glaciation, was probably induced by a geologically sudden, high uplift of the northeastern part of the continent; and in the Upper Mississippi region, according to Chamberlin and Salisbury, the differential elevation, increasing from south to north, was 800 or 1000 feet. As an uplift of the continental plateau, but without much disturbance of its mountain ranges and of the general contour of the great interior area, this movement appears to have embraced the entire width of the country, raising the Rocky, Sierra Nevada, and Cascade mountains to such altitude that large tracts became covered by glaciers.

Influenced by the changed climatic conditions, with increase in the precipitation of snow and rain, and decrease in the rate of evaporation, many enclosed basins of the arid region, which had previously been dry or only occupied by shallow lakes, became filled almost or quite to overflowing. Two of these Quaternary lakes, especially important because of their size, namely, Bonneville in Utah and Lahontan in Nevada, have been described respectively by Gilbert and Russell in monographs of the U. S. Geological Survey. Each of these lakes is found to have a history of two epochs of humidity, with great rise of their waters, divided by a very dry epoch, in which they were lowered by evaporation until little or no water remained. These lacustrine and interlacustrine stages in the Great Basin do not appear, however, to represent the first and second Glacial epochs of the northeastern states, with their interglacial epoch; but, as indicated by their place in the sequence of Quaternary events, they seem referable to the

* This Journal, III, vol. xxxii, pp. 167–181, Sept., 1886, and vol. xxxviii, pp. 257–263, Oct., 1889. U. S. Geol. Survey, Eighth Annual Report, pp. 428–432.

second Glacial epoch, showing that it was more prolonged and complex there than eastward. Indeed, so definite subdivision of the lacustrine history of the arid region, and its relationship with the glaciers, living and extinct, of that region and of the country thence north to Alaska, lead us to ask whether there has not been a third as well as a second Glacial epoch, the last affecting chiefly the far west and far north.

Recession and final melting of the ice-sheet of the second Glacial epoch from the Upper Mississippi basin, the Laurentian lakes, and New England, took place only 7,000 to 10,000 years ago, according to estimates by Prof. N. H. Winchell, from the rate of the postglacial erosion of the falls of Saint Anthony;* by Dr. Andrews, from the erosion of the bluffs bordering Lake Michigan, and the resulting accumulation of sand beaches and dunes about the south end of the lake;† by Professor Wright, from the formation of valleys by streams tributary to Lake Erie;‡ by Mr. Gilbert, from the Niagara gorge and falls;§ and by Professor Emerson, from alluvial deposits of the Connecticut River.‖ The moraines stretching from Nantucket and Cape Cod west to the Dakotas, Manitoba and Assiniboia, are thus referred to a surprisingly late epoch, almost verging upon the historic period of dawning civilization in Egypt, China and India. The first great rise of Lakes Bonneville and Lahontan was apparently contemporaneous with the ice-sheet of the second Glacial epoch, which formed these moraines, and with the maximum extension of glaciers in the western Cordilleran region. After this there followed a very dry climate in the far west, as shown by the Bonneville and Lahontan sediments and shore-lines, corresponding doubtless to the time of departure of the last ice-sheet from the northern United States and the greater part of Canada.

The second rise of Lakes Bonneville and Lahontan belongs to a later time when the far west again had a plentiful precipitation, which was largely snowfall on the Sierra Nevada and northward through British Columbia and Alaska, causing a great development of glaciers and ice-sheets upon the Pacific side of our continent. The date of this glaciation, which may be called our third Glacial epoch, was, according to Russell, "hundreds, but not thousands, of years ago."¶ It is probable

* Geology of Minnesota, Fifth Annual Report, for 1876; and Final Report, vol. ii, 1888, pp. 313–341. Quart. Jour. Geol. Soc. London, vol. xxxiv, 1878, pp. 886–901.

† Transactions of the Chicago Academy of Sciences, vol. ii.

‡ The Ice Age in North America, p. 466.

§ Proceedings, Am. Assoc. Adv. Sci., vol. xxxv, for 1886, p. 222. "The History of the Niagara River," Sixth An. Rep. of Commissioners of the State Reservation at Niagara, for 1889, pp. 61–84.

‖ This Journal, III, vol. xxxiv, pp. 404–5, Nov., 1887.

¶ U. S. Geol. Survey, Monograph xi, Geological History of Lake Lahontan, p. 273. Bulletin, G. S. A., vol. i, p. 142.

that this return of glacial conditions affected also the Mackenzie basin and the country bordering Hudson Bay, as seems to be indicated by the observations of Dr. Robert Bell.* In New England and the Saint Lawrence region, and in Greenland, Iceland, northwestern Europe, and even Spitzbergen, this refrigeration, following an interval of somewhat warmer climate than that which prevails at the present time, has caused the isolation of colonies of southern mollusks whose geographic range must have been formerly continuous from southern latitudes; and corresponding changes in the forests and other flora of the land are discovered in European peat-bogs.† Very probably these recent climatic changes, both marine and terrestrial, in the North Atlantic region, have been due in large measure to variations in the volume of the Gulf Stream;‡ but in the Cordilleran area, from the Sierra Nevada and the contiguous great Quaternary lakes north to Alaska, the increased precipitation of rain and snow and the extension of glaciers, constituting for that area a third Glacial epoch, were probably caused by elevation of that side of the continent. Evidences of very late uplifting of our Pacific coast, followed now by subsidence, in harmony with this explanation of the late glaciation there, have been observed by Dr. G. M. Dawson, but the extent of this uplift may have greatly exceeded his estimate.§

What has been the length of the Quaternary era, we cannot yet determine with very close approximation; but from the extent of river erosion during the principal interglacial epoch, and from many other correlative observations, McGee concludes, as it seems to me reliably, that the interval between the first and second Glacial epochs was several times longer than the interval between the close of the second Glacial epoch, when the latest ice-sheet of the northeastern United States was melted away, and the present day.‖ In proportion with the estimates of 7,000 to 10,000 years for the time since that glacial recession, it appears probable that the whole Quaternary era, including the stages of glaciation and the warm intervals of retreat or complete departure of the ice-sheets, that is, all the period from the end of the Pliocene till now, may be 100,000 or 200,000 years. Though the earliest glaciation is thus apparently referable to some part of the last stage of maximum eccentricity of the earth's orbit, the astronomic theory so ably advocated by Croll seems untenable, not only from the mete-

* Bulletin, G. S. A., vol. i. p. 308.

† This Journal, III, vol. vii, pp. 134–8, Feb., 1874. James Geikie, Prehistoric Europe, chapters xx and xxi.

‡ American Geologist, vol. vi, pp. 336–7, Dec., 1890.

§ Canadian Naturalist, new series, vol. viii, pp. 241–8, April, 1877.

‖ This Journal, III. vol. xxxv, pp. 465–6, June, 1888. U. S. Geol. Survey, Seventh Annual Report, pp. 637–9.

orologic objections of Woeikof, but also from the recurrence of intense glacial conditions during the second and third epochs of glaciation, long after the earth's eccentricity had diminished to its present long minimum stage.

The western margin of the drift spread upon the northern part of the great plains, in Alberta, belonging to the first Glacial epoch, overlies moraines of the Rocky Mountain glaciers; and it seems most probable that this earliest epoch of glaciation brought the maximum extension and thickness of ice in British Columbia, where Dr. Dawson finds that it overtopped mountains from 5,000 to 7,200 feet above the sea.* Continuous land-ice, broken only by the projecting highest Cordilleran ranges, then extended, if my interpretation of the origin of the drift deposits of our interior area is true, from New England, Newfoundland and Labrador, to Vancouver Island, the upper part of the Yukon basin, and the Arctic Sea east of the Mackenzie River. But the division of this ice-covered area by the main Rocky Mountain range, rising, at least in portions of its course, above the *mer de glace*, and containing glaciers in its alpine valleys, may well be recognized by the names Laurentide and Cordilleran, proposed by Dr. Dawson respectively for the ice-sheet of the northeastern part of our continent and for that covering British Columbia. The thickness of the Laurentide ice-sheet of the first Glacial epoch, along its belt of maximum development, was probably 3,000 to 6,000 feet over central Newfoundland and Labrador, increasing to 10,000 or 12,000 feet on the Laurentide highlands and in the basin of James Bay and over the south part of Hudson Bay, but thence decreasing to 8,000 or 7,000 feet in the region of Reindeer and Winnipeg Lakes, and farther west to only 2,000 or 1,500 feet at the Cypress and Sweet Grass hills; while the central part of the Cordilleran ice-sheet, according to Dawson, was from 2,000 to 6,000 feet thick, lying on a very uneven mountainous country. I have estimated the area of North America covered by these ice-sheets as about 4,000,000 square miles, and the probable average thickness of the ice about 3,600 feet, or two-thirds of a mile.†

The ice-sheet of the second Glacial epoch had an ascending slope of twenty to thirty feet per mile from its southern border to Mt. Katahdin, the White Mountains, and the Adirondacks, where its altitude was about one mile above the present sea level, with a thickness of 4,000 to 5,000 feet above the land surface. Its greatest thickness, estimated by Dana to have been 11,000 feet, was on the Laurentide highlands, be-

*Geological Magazine, III, vol. vi, pp. 350–2, Aug., 1889. Am. Geologist, vol. vi, pp. 153–162, Sept., 1890.

†The Ice Age in North America, p. 579. Am. Geologist, vol. iv, pp. 165–174 and 205–216, Sept. and Oct., 1889.

tween Montreal and Hudson bay, as is indicated by the general divergence of striæ and dispersal of drift from that area. This ice-sheet was probably 6,000 feet thick over Reindeer and Winnipeg lakes, but westward it declined to its outermost terminal moraine east of the Hand, Cypress, and Sweet Grass hills, which had been islands surrounded by ice during the the earlier glaciation. In the far western Cordilleran region, however, the ice of the second and third Glacial epochs probably nearly equalled, or in some portions exceeded, that of the first. While the second glaciation fell short of the earlier in the Mississippi basin and on the great plains, it passed beyond that on the Atlantic coast; and likewise, with the third glaciation, it covered and obliterated most of the earlier glacial records in the Rocky Mountains and westward. Throughout the drift-bearing area traces of the last glacial movements, and of the conditions attending the retreat of the latest ice-sheet, are much better preserved than those of preceding stages in the Glacial period; and similarly the relative levels of land and sea at the time of disappearance of the ice are displayed very clearly.

Jamieson twenty-five years ago suggested that the ice of the Glacial period might cause a subsidence of the earth's crust beneath it, because of the pressure of its immense weight, the crust being supposed by him to rest, in accordance with the laws of equilibrium of flotation, upon the heavier molten interior of the earth.* Subsequent researches of glacialists strongly support this opinion, for most countries that have been ice-covered, though previously much elevated, are found to have stood lower than now in relation to the sea level when the ice disappeared, since which time they have risen to their present height. In the interior of this continent the depression of the land beneath the ice-sheet of the first Glacial epoch is shown by the loess of the Missouri and Mississippi basins, which seems to be a deposit of broad slackened river floods and of shallow lakes adjoining the ice-front. On the Atlantic coast the Champlain subsidence attending the close of the second Glacial epoch is known, from fossiliferous marine beds overlying the till, to have been slight in northeastern Massachusetts, 150 to 230 feet in New Hampshire and Maine, nothing or of small amount in Nova Scotia, but considerable, with increase from east to west, along the lower Saint Lawrence valley, being 375 feet opposite the Saguenay, and 520 feet at Montreal, but thence diminishing southward along lake Champlain and westward in the upper Saint Lawrence and Ottawa valleys. The country southwest of Hudson bay sank 300 to 500 feet, Labrador 1,000 to 1,500 feet, and western Greenland

* Quart. Jour. Geol. Soc. London, vol. xxi, 1865, p. 178.

and Grinnell Land 1,000 to 2,000 feet. Again, in British Columbia and the Queen Charlotte Islands, Dr. Dawson and others find proofs of submergence, ranging up to 200 or 300 feet, while the glacial conditions still endured.

Northwestern Europe, also, had a much greater altitude during the later part of the Tertiary era, in which Scandinavia and the British Isles suffered vast denudation, with erosion of fiords and channels that are now submerged 500 to 800 feet beneath the sea. The maximum preglacial elevation probably exceeded the depth of the Skager Rack between Denmark and Norway, which is 2,580 feet, with a deep submerged valley running from it west and north to the abyssal Arctic ocean.* Under the weight of its ice-sheet, the glaciated area of Europe, like that of North American, sank mostly to a somewhat lower level than it now has, the maximum depression in Scotland, Sweden and Norway, and Spitzbergen, being 500 to 580 feet.† From this depression Scandinavia has gradually risen, with pauses, during which beaches were formed; and the uplift of that peninsula, as of the country about Hudson bay, continues to the present day.‡

The climatic conditions of the Ice age were very favorable for the production of river floods. During the times of great continental elevation and the accumulation of ice-sheets, the highlands and mountains south of the glaciated areas received in the winters far more snowfall than now, and in the summers this was melted fast, giving the streams far greater volume during their stages of flood than at the present time. The approximate parallelism of the southern boundary of the ice-sheets with the present isothermal lines and with belts of equal precipitation of rain and snow, indicates that the distribution of heat and the courses of storms were somewhat the same as now. It seems to be proved, however, by the abundant occurrence of Pleistocene fossils on the isthmus of Panama, "all living up to the present time," collected by Dr. G. A. Maack up to the height of 763 feet,§ that the lower portions of this isthmus were submerged once, or perhaps repeatedly, during the Glacial period, permitting the warm equatorial current of the Atlantic to continue right onward into the Pacific ocean, instead of flowing northeastward out of the Gulf of Mexico. A large amount of warmth would thus be withdrawn from the northern Atlantic area. It is also probable that the part of the bed of the North Atlantic stretching

* Nature, vol. xxiii, p. 393, with map of submarine contour.

† Am. Geologist, vol. ii, pp. 375–6, Dec. 1888. Geol. Mag., III, vol. vi, 1889, pp. 157–8. Nature, vol. xv, p. 123, and vol. xxxii, p. 555.

‡ Nature, as last cited, and vol. xxxix, pp. 488–492.

§ Reports of Explorations for a Ship Canal, Isthmus of Darien, Navy Department, Washington, 1874, pp. 155–175.

from France and Great Britain to the Færöe islands and thence to Iceland and Greenland was uplifted to form a continuous land surface, remaining thus so long as to be a bridge for the migration of the European flora after the departure of the ice.* On the whole, however, there was probably not less evaporation from the sea, and not less precipitation from the clouds, than now. Upon the most elevated areas the moisture received from the clouds was temporarily stored as ice; while in contiguous mountain districts, as the southern Appalachians, the excessive winter snows were each year melted and poured down in floods across the plains between the mountains and the ocean. And on the glaciated areas, when the ice-sheets were at any time forced to retreat, and especially during their final melting, great floods of water from the dissolving ice and from accompanying rains swept down from the ice-surface, filling the valleys of the adjoining land and spreading over its plains in their seaward course.

Unusually abundant detritus was supplied to the Quaternary river floods, both on unglaciated areas and on tracts that had been ice-covered. For example, our southern Appalachian district had been subjected to very long continued subaërial denudation under a more equable climate and at less altitude during the Tertiary era, and a large amount of detritus rested on the mountain slopes and in the high valleys, ready to be carried away to the lower plains by the swollen rivers at times of Quaternary uplifts of the continent and northern glaciation. Within the ice-sheets, too, much drift was gathered up from the general land surface over which the ice slowly moved outward from its central area; and especially the sides of hills and mountains, rasped by the overriding ice, yielded plentiful bowlders and coarse and fine rock-débris, which was borne forward as englacial drift, to become part of the ground moraine farther on, or to be dumped in the terminal moraines, or, not reaching these, to be exposed on the surface of the ice during its departure. The osars and kames, and the abundant stratified drift of valleys and plains in glaciated countries, show that the amount of englacial drift was large, and that much of it was carried off to form these deposits by the flooded rivers that descended from the melting ice.

Attempting a correlation of the Quaternary fluvial deposits of this country, we may notice first those which were formed upon areas beyond the limits of the glacial drift. In the southern Atlantic states the Appomattox and Columbia formations, described by Mr. McGee as marine beds, characterized by coarse cobble and gravel deposits, with ice-borne bowlders,

* Andrew Murray, Geographical Distribution of Mammals, 1866, pp. 37–42. James Geikie, Prehistoric Europe, 1881, pp. 518–522, and p. 568, with plate E.

along the rivers, and prevailingly finer gravels, sand, clay and silt between the rivers, seem to me referable to fluvial action, dependent on the conditions already noted, without submergence by the sea, during times of great Quaternary elevation of the continent, while its northern part was becoming covered with the ice-sheets of the first and second Glacial epochs. The lack of fossils accords better with such deposition by flooded rivers; and, in harmony with this view, the stratigraphic relations indicate for the Appomattox an early Quaternary age, and for the Columbia a much later age, yet antedating that of the terminal moraines and stratified valley drift of the adjacent glaciated area of Pennsylvania, New Jersey, and Long Island, which belong to the culmination, and in larger part to the stages of recession, of the later ice-sheet.*

In the lower Mississippi basin, the great uplift introducing the earlier glaciation seems to have been marked by so excessive precipitation and heavy river-floods that thick deposits of sand and gravel, constituting the principal mass of the "Orange Sand," were filled into the channel which had been cut by the river in the Tertiary beds of its lower course while it was above the sea level, but had only a moderate elevation, during the greater part of the Pliocene period. About the time of the maximum extension of the ice-sheet of the first Glacial epoch, this basin was depressed to approximately the height which it now has, but with less descent in its slope seaward, as shown by the loess. On account of the diminished transporting power of its floods, deposition along the lower valley ceased for a time, and the "Orange Sand" was partially eroded, until at length the floods and silt supplied by the melting of the ice-sheet filled the newly formed channel, and overspread the gravel and sand areas, depositing the Port Hudson beds and loess. During the long interglacial epoch these beds, with the "Orange Sand," were immensely eroded, and more especially at the time of northward elevation initiating the second Glacial epoch. Again, from the melting of the later ice-sheet, vast floods, bringing some gravel and sand, but more fine silt or loess, poured down this valley, spreading their deposits along the bottom of the interglacial channel in a flood-plain 200 to 300 feet below the uplands and sixty miles wide from Cairo southward; and, at a diminished rate, the deposition of the river silt over this bottom-land is still going on at every flood stage.†

* This Journal, III, vol. xxxv, Feb., and April to June, 1888; vol. xl. pp. 15–41. July, 1890; and vol. xl, pp. 237–8, Sept., 1890.

† E. W. Hilgard, this Journal, II, vol. xlii, May, 1866; vol. xlvii, Jan., 1869; vol. xlviii, Nov., 1869; III, vol. ii, Dec., 1871. T. C. Chamberlin, Bulletin Geol. Soc. of America, vol. i, 1890, pp. 469–480.

Quaternary silt deposits, closely related to the loess, form broad expanses in the Great Basin and in the San Joaquin valley of California, attaining depths of at least 1,500 to 2,000 feet and more, as is known by artesian borings which at these depths fail to reach the bed-rock. These deposits consist mainly of fine-grained calcareous earth or clay, porous, gray to yellow in color, which is used by the Indians and Mexicans for the manufacture of sun-dried bricks, known by the Spanish name "adobe." This name is also used for the earth from which the bricks are made, and Russell has therefore adopted it for this extensive geologic formation of the arid region. Its broad flat tracts are bordered by steep mountain ranges, and others rise from it like islands. The origin of the adobe, as Russell has shown, is from the waste of the mountain slopes, chiefly through the action of ephemeral rills and streams, born of passing showers.* Though it is still increasing in thickness, evidently far the greater part of this formation was deposited before the humid epochs recorded by lakes Bonneville and Lahontan, but after the early Quaternary orographic movements which produced the grand topographic features of the region. It belongs therefore mainly to the first Glacial epoch and the ensuing long interglacial epoch.

Russell has solved the difficult problem of the loess of China by comparing it with the adobe; and the great Quaternary deposits of the Mississippi valley, and of the coastal plain of the Southern States, find analogues in the basins of the Amazon and La Plata, of the Rhine and the Po, of the Nile, of the Indus and Ganges, of the Yang-tse Kiang and Hwang Ho, and of the Lena, Yenisei, and Obi. In particular, we may compare the great Indo-Gangetic plain, which stretches across India south of the Himalayas, with the Appomattox and Columbia formations. This immense alluvial plain, the richest and most populous portion of India, covers about 300,000 square miles, rising from the sea level to an elevation exceeding 900 feet on the water-shed between the Indus and the Ganges. Its prevailing formation is fine silt or clay, more or less sandy, with gravel near the borders of the plain. Its central portions have a thickness of at least 400 to 700 feet, as determined by borings which do not at these depths reach the bottom of the alluvium; and this entire deposit, according to Medlicott and Blanford, is of Quaternary age and of fresh-water origin, having been laid down by the flood stages of the rivers that descend from the very rainy southern slopes of the Himalayan range.†

The stratified or modified drift, gathered from the ice-sheet by superglacial and subglacial rivers, and spread beyond its

* Geol. Magazine, III. vol. vi, pp. 289–295 and 342–350, July and August, 1889.

† Manual of the Geology of India. 1879, Part i, pp. 391–421. Quart. Jour. Geol. Soc. London, vol. xix, 1863, pp. 321–354.

area, most abundantly during stages of glacial recession, has been observed and often well described and mapped in all glaciated countries which have received study, but perhaps nowhere else so fully as in the valley of the Connecticut river.* This beautifully terraced valley, the terraces and plains of the Merrimack river, and the osars and associated plains of Maine which Stone has so well described, illustrate the formation of the modified drift deposits where free drainage could take place from the border of the ice-sheet. Beds of gravel, sand and clay filled the Connecticut and Merrimack valleys to the level of their highest terraces, which are remnants of the glacial flood-plain, and the lower terraces record stages of the subsequent erosion. Every large river valley running southward within our glaciated area has had an interesting history, which may be discovered by study of its stratified drift. Owing to the northern depression of the land under the ice-weight, the descent of these valleys when first uncovered from the ice was generally less than now. In the Hudson valley the changed levels appear to have included not only subsidence at the north, which admitted the sea to the basin of lake Champlain, but also elevation of the present coast above the sea on the latitude of New York city and southward, so that while the ice-front was receding along this valley from south to north it held a lake from Manhattan island to Albany and Lake Champlain, until the farther glacial retreat allowed this long narrow lake to be mainly drained northward into the Champlain arm of the sea. In the Mississippi basin the northern subsidence probably produced broad shallow lakes along the border of the earlier ice-sheet, preventing the accumulation of terminal moraines and extending a mantle of loess over the till as the ice melted. Basins now draining northward, also, as of the Contoocook river in New Hampshire, the great lakes tributary to the Saint Lawrence, and the Red river of the North, held glacial lakes due to obstruction on the north by the ice-barrier. The old shore-lines of these glacial lakes are found to have now an ascent from south to north, caused by differential rise of the land after it was relieved from its load; and the successive beaches of Lake Agassiz, the largest of these lakes, which occupied the basin of the Red river and Lake Winnipeg, show that this upward movement was in progress simultaneously with the departure of the ice.

* C. H. Hitchcock, Geol. of Vt., vol. i, 1861, pp. 93–118. J. D. Dana, Trans. of the Conn. Acad. of Arts and Sciences, vol. ii, 1870, pp. 45–112; and many papers in this Journal, III, vols. i, ii, v, x–xiii, xv, xxii–xxvii, 1871–1884, etc. Warren Upham, Geol. of N. H., vol. iii, 1878, pp. 3–61; and this Journal, III, vol. xiv, pp. 459–470, Dec., 1877.

SUCCESSION OF EPOCHS, GLACIAL AND FLUVIAL DEPOSITS, AND

GLACIAL PERIOD OF ICE AGE. PLEISTOCENE PERIOD.

EPOCHS.	EASTERN PROVINCES AND NEW ENGLAND.	MIDDLE AND SOUTHERN ATLANTIC STATES.
RECENT OR TERRACE. (Mostly within the period of traditional and written history.)	Rise of the land to its present height, or somewhat higher, soon after the departure of the ice. Rivers eroding their glacial flood-plains, leaving remnants as terraces. Warmer climate than now, probably due to greater Gulf Stream, formerly permitted southern mollusks to extend to Gulf of St. Lawrence, now represented by isolated colonies.	Continued subsidence of coast at New York and southward, and rise of the mountainous belt, by displacement along the fall line of the rivers. Much erosion of the Columbia formation since culmination of second Glacial epoch; sedimentation in bays, sounds, and estuaries.
CHAMPLAIN. (Close of the second Glacial epoch.)	Land depressed under ice-weight; glacial recession; continued deposition of upper till and deep flood-plains of gravel, sand and clay (modified drift). Terminal moraines marking pauses or re-advance during general retreat of ice. Marine submergence 150 to 230 feet on coast of Maine, 0 to 520 feet in Gulf and valley of St. Lawrence.	Less subsidence in latitude of New York and southward than at north; lower Hudson valley, and part of its present submarine continuation, above sea level. Gravel and sand deposits from englacial drift in Delaware and Susquehanna valleys, enclosing abundant human implements at Trenton, N. J.
SECOND GLACIAL.	Second great uplift of the land, 3,000 to 4,000 feet higher than now; snowfall again all the year; ice probably two miles thick on Laurentide highlands, and extending somewhat farther south here than in first glaciation. Lower till (ground moraine), and upper till (englacial drift). Terminal moraines, kames, osars, valley drift.	Renewal of great continental elevation (3,000 feet in latitude of New York and Philadelphia), of excessive snowfall and rains, and of widespread fluvial deposits, the Columbia formation, on the coastal plain, during early part of this epoch. Implements of man at Claymont, Delaware.
INTER-GLACIAL. (Longest epoch of this era.)	Ice-sheet melted here; probably not more ice in Arctic regions than now. Fluvial and lacustrine deposits of this time, with those of the first Glacial epoch, were eroded by the second glaciation.	Depression, but generally not to the present level. Deep channels cut in the bed-rocks by the Delaware, Susquehanna, Potomac and other rivers. The Appomattox deposits much eroded. Relative length of this epoch made known by McGee from study of this region.
FIRST GLACIAL.	Begun by high continental uplift, cool climate and snowfall throughout the year, producing ice-sheet. Much glacial erosion and transportation; till and stratified deposits. Ended by depression of land; return of warm climate, with rain; final melting of the ice. Isthmus of Panama probably submerged (Gulf Stream smaller), and again in second Glacial epoch.	Continental elevation; erosion of Delaware and Chesapeake bays, and of Albemarle and Pamlico sounds. Plentiful snowfall on the southern Appalachian mountains; snows melted in summer, and heavy rains, producing broad river-floods, with deposition of the Appomattox formation.

CHANGES IN ALTITUDE AND CLIMATE, DURING THE QUATERNARY ERA.

MISSISSIPPI BASIN AND NORTHWARD.	CORDILLERAN REGION.	EUROPE AND ASIA.
Terracing of river valleys. Northward rise of area of Lake Agassiz nearly complete before the ice was melted on the country crossed by Nelson river; but rise about Hudson bay is still going on. 7,000 to 8,000 years since ice-melting uncovered Niagara and falls of St. Anthony.	Including a stage of considerable uplift, with return of humid conditions, alpine glaciation (third Glacial epoch), and the second great rise of Lakes Bonneville and Lahontan. Very recent subsidence and change to present aridity.	Erosion and terracing of stratified drift in river valleys. Land passage of European flora to Greenland; succeeded by subsidence there, admitting warm currents to Arctic sea. Minor climatic changes, including a warmer stage than now. Upper and outer portions of Indo-Gangetic alluvial plain; extensive deposits of Hwang Ho, and destructive changes of its course.
Abundant deposition of englacial drift. Stone implements in river gravels of Ohio, Ind., and Minn. Laurentian lakes held at higher levels, and Lake Agassiz formed in Red river basin, by barrier of retreating ice, with outlets over lowest points of their present southern water-shed. Marine submergence 300 to 500 feet on southwest side of Hudson bay.	Depression probably almost to the present level. Restoration of arid climate; nearly or quite complete evaporation of Lakes Bonneville and Lahontan. Formation of the "adobe" continuing through the second Glacial, Champlain and Recent epochs.	Final departure of the ice-sheets; glacial rivers forming eskers and kames. Loess deposited while the region of the Alps was depressed lower than now. Upper (englacial) till, and asar, of Sweden. Marine submergence 500 to 600 feet in Scotland, Scandinavia, and Spitzbergen.
Ice-sheet here less extensive than in the first Glacial epoch, and not generally bordered as then by lakes in valleys which now drain southward. Terminal moraines at extreme limit of the ice-advance, and at ten or more stages of halt or re-advance in its retreat.	Probable uplift 3,000 feet, shown by submerged valleys near Cape Mendocino. Second ice-sheet on British Columbia and Vancouver island; local glaciation of Rocky Mts., Cascade range, and Sierra Nevada, south to lat. 37°. First great rise of Lakes Bonneville and Lahontan.	Second elevation and general glaciation of northwestern Europe; the ice-sheets of Great Britain probably more extensive than in first Glacial epoch. Oscillations of ice-front; British Lower and Upper bowlder-clays, the Chalky, Purple and Hessle bowlder-clays. Terminal moraines in Germany.
Depression nearly to present level southward; more northward, but followed there by differential uplift of 800 or 1,000 feet. Great erosion of loess and other modified drift, and of "Orange Sand." Valleys of this epoch, partly filled with later till, are marked by chains of lakes in southern Minnesota.	Continental depression. Arid climate. Long continued denudation of the mountains; resulting very thick subaërial deposits of "adobe." Intermittent volcanic action in various parts of this region, throughout the Quaternary era to very recent times, and liable to break forth again.	Recession, or probably complete departure, of the ice-sheets. Land connection between Europe and Africa, permitting southern animals to extend far northward. Erosion of the Somme valley below its oldest implement-bearing gravels.
Pliocene elevation of continent brought to culmination at beginning of Quaternary era; this whole basin probably then uplifted 3,000 feet; excessive snowfall and rain; deposition of the "Orange Sand." Ice-sheet south to Cincinnati and St. Louis, at length depressing the earth's crust beneath it; slackened river floods and shallow lakes, forming the loess.	Latest rise (3,000 feet) of the Sierra Nevada and other Great Basin mountain ranges formed by immense uplifts, with faulting. California river-courses changed; human bones and implements in the old river-gravels, lava-covered. Ice-sheet on British Columbia; local glaciers southward.	Uplift and glaciation of the Colorado Cañon district. northwestern Europe; maximum elevation 2,500 feet or more (depth of the Skager Rack); France and Britain united with the Færöe islands, Iceland and Greenland. Uplifts of the Himalayas and other mountain ranges attendant on both Glacial epochs.

Not until the Quaternary era are certain proofs found of the appearance of man. During the earliest epoch of this era his implements and even his bones were entombed in the deep auriferous gravels of California, while great uplifts, with faulting and outflows of lava, were turning the rivers into new courses. Stone implements have also been found in the much later Columbia formation in Delaware, which is here referred to the time of continental uplift at the beginning of the second Glacial epoch, and in the modified drift of Trenton, N. J., of southern Ohio and Indiana, and of central Minnesota, deposited during the stages of culmination and recession of the ice-sheet of that epoch. Nearly of the same age, probably, is the little image from an artesian boring through fluvial beds, which enclose a lava-sheet, at Nampa, Idaho; but the inhumation of the obsidian spear-head discovered by McGee in the upper sediments of Lake Lahontan belongs to a still later and indeed recent time.

The accompanying table presents a correlation of the successive Quaternary epochs and formations, in descending order from the present time to the beginning of this era, as reviewed in the preceding pages.

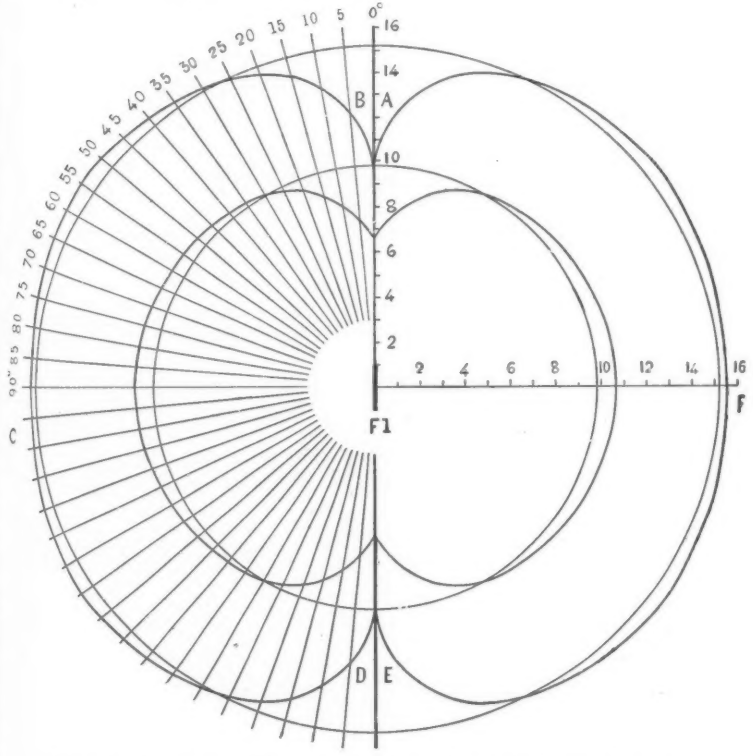
ART. VII.—*On the illuminating power of Flat Petroleum Flames in various azimuths;* by ALFRED M. MAYER.

THIS paper contains the results of two series of measurements of the amount of light given out in various azimuths by two petroleum flames. One of these was the flat flame of a Hitchcock lamp in which the combustion is maintained by a blast of air driven against the flame by a fan moved by clock work. This flame is not surrounded by a chimney. The other flame was the flat flame of an ordinary petroleum lamp inclosed by a chimney.

The accompanying diagram expresses graphically the results of these experiments. The flat flame is shown by the thick line Fl. The polar coördinates of the closed curve A, B, C, D, E, F, give, by the aid of the scale of candle power Fl, A, or Fl, F, the amount of light given out by flame in various azimuths. The zero of angle is in the plane, A, E, of the flat flame. The inner and similar curve is the photometric curve of the flat flame of an ordinary petroleum lamp. The circles cutting these two curves are the photometric curves that would be given by the respective flames, if the light which each flame gives was equally distributed in all azimuths.

The following table gives the candle power of each flame at azimuths differing by 5°. The photometric measures are the mean of six series of experiments.

Azimuth.	Hitchcock flame.	Ordinary flame.	Azimuth.	Hitchcock flame.	Ordinary flame.
0	9·8	6·6	56	15·8	10·25
5	12·25	7·45	55	15·8	10·35
10	13·5	8·15	60	15·8	10·4
15	14·3	8·8	65	15·75	10·44
20	14·8	9·35	70	15·65	10·55
25	15·15	9·65	75	15·6	10·6
30	15·35	9·85	80	15·6	10·6
35	15·55	10·0	85	15·6	10·6
40	15·65	10·1	90	15·6	10·6
45	15·75	10·2			



The flame of the Hitchcock lamp gives 15·6 candle power in azimuth 90°, and only 9·8 candle in azimuth 0°; that is, the edge of the flame gives about 37 per cent less than the flat surface. The flat flame of the ordinary petroleum lamp gives

in azimuth 90°, 10·6 candles; in azimuth 0°, 6·6 candles of light; that is the edge of the flame gives about 38 per cent less light than that given by the side. The flame of the Hitchcock lamp and the flame of the ordinary petroleum lamp with chimney increase in candle power with the azimuth in different rates. The reason of this is that the glass chimney acts as a reflector and tends to equalize the illumination in different azimuths. The photometric curve of the Hitchcock flame cuts the circle of average illumination at 26¾°; the curve of the ordinary petroleum flame cuts its circle of average illumination at 30° of azimuth. A flat coal gas flame does not (to me) show any difference in candle power, when its edge or flat side is presented to the ordinary Bunsen photometer.

As to the cause of the absorption of light, or, of the opacity to light of a petroleum flame I have no hypothesis to offer; nor have any of the experiments I have made on the absorption action of this flame given me any clue as to its cause. As a friend observed, all we can say is that the gas house does for the gas of the coal gas flame what the lamp does not do for the gas of its flame.

Stevens Institute of Technology, Hoboken, N. J.

Art. VIII.—*On the Physical Properties of Hard-Rubber, or Vulcanite;* by Alfred M. Mayer.

The discovery of the large coefficient of expansion of hard-rubber by Kohlrausch,* in 1873, and of its remarkable diathermancy by Bell,† in 1880, attracted the attention of physicists to this substance. In this paper I give additional and more minute experiments on the above mentioned and other properties of this substance ‡

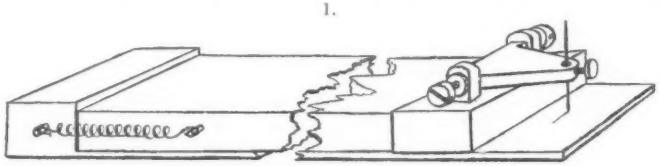
* Pogg. Ann., cxlix. 577, 1873. † This Journal, Oct. 1880.

‡ In his paper "On the Production and Reproduction of Sound by Light," this Journal, Oct. 1880, Mr. Bell gives, among other interesting experiments, those on vulcanite. A revolving disc, perforated with holes, produced rapidly recurring flashes of solar rays which impinged on selenium through which passed an electric current. In this circuit were two receiving telephones. The flashes of light caused synchronous alterations in the resistance of the selenium and in the electric current traversing it; so that when two receiving telephones, in the circuit, were placed to the ears a sound was perceived: the frequency of whose vibration corresponded to the frequency of the flashes of light. Mr. Bell writes: "We have made experiments with the object of ascertaining the nature of the rays that affect selenium. For this purpose we have placed in the path of an intermittent beam various absorbing substances. When a solution of alum, or bisulphide of carbon, is employed, the loudness of the sound produced is very slightly diminished, but a solution of iodine in bisulphide of carbon cuts off most, but not all, of the audible effect. Even an apparently opaque sheet of hard rubber does not entirely do this. This observation which was first made in Washington, D. C., by Mr.

Hard-rubber, vulcanite, or ebonite, as it is variously called, is formed of rubber and sulphur. These are combined in proportions of about two parts of rubber to one of sulphur. These ingredients, intimately mixed, are by the action of a temperature of 300° F., lasting three hours, converted into a black compound. The sun viewed through thin plates of this substance appears of a deep red color. The hard-rubber used in our experiments was formed of 64 parts of rubber of Para and 34 parts of sulphur.

The coefficient of linear expansion was obtained with the apparatus devised by me for this purpose and shown in the accompanying figure. A plate of steel one meter long and 6^{cm} broad had a lug of steel 15^{mm} broad screwed on to its end to act as an abutting piece against which the end of the bar of vulcanite, 96^{cm} long 6^{cm} broad and $1{\cdot}3^{cm}$ thick, was pressed by means of springs, as shown in figure 1. A block of steel,

1.



carrying a tracer, while bearing against the end of the bar of vulcanite was slid along the end of the bar and traced on the surface of the steel bar a very fine line. The bars are in a closed case in which they have remained for twenty-four hours. The temperature is taken from thermometers lying on the vulcanite bar. After having traced the line the apparatus is placed in a metal case surrounded by ice and after the temperature has become stationary another line is cut by the tracer. The bar in falling through the observed temperature has shortened by the distance between the lines less the shrinkage of the steel bar. The distance between the lines is measured by a micrometer microscope. As the tracer is of steel its con-

Tainter and myself, is so curious and suggestive that I give in full the arrangement for studying the effect. When a sheet of hard rubber, A, was held as shown in the diagram, the rotation of the disc or wheel B, interrupted what was an invisible beam, which passed over a space of several meters before it reached the lens C, which finally concentrated it upon the selenium cell D. *A faint but perfectly perceptible musical tone was heard from the telephone connected with the selenium* that could be interrupted at will by placing the hand in the path of the invisible beam . . . . the effect is produced through two sheets of hard rubber having between them a saturated solution of alum. The anomalous behavior of the hard rubber alluded to above suggested the thought of listening to it also. This experiment was tried with extraordinary success. I held the sheet in close contact with my ear while a beam of intermittent light was focussed on it by means of a lens. A distinct musical note was immediately heard. We found the effect intensified by arranging the sheet of hard rubber as a diaphragm, and listening through a hearing tube."

traction is the same as that of the steel bar on which it rests, so that we have only to consider the length of the steel plate equal to that of the vulcanite bar in computing the coefficient of expansion of the vulcanite. Calling this length l, the distance between the lines d, the coefficient of expansion of the steel k, and the coefficient of expansion of the vulcanite e, we have in the range of temperature t,

$$e = \frac{d \div l}{t} + k$$

The mean of twelve determinations thus made between 0° C. and 18° C. gave ·0000636 as the mean coefficient in the above range of temperature.

The formula of the cubical expansion of ebonite was determined by a mercurial thermometer made of a bulb of ebonite to which was attached a glass capillary tube of cylindrical bore, as shown in figure 2, the tube of vulcanite was placed in a metal shield to protect it from moisture and it and the glass tube surrounded with ice. The distance of the mercury from a fine line engraved on the glass tube was read with a cathetometer when the level of the mercury had become stationary, and the lengths between the line and the level of the mercury at different temperatures, obtained by heating the apparatus in a hot air chamber furnished with a thermostat, were measured. Knowing the capacity of the ebonite bulb and of a millimeter in length of the glass tube we obtained the rate of the apparent expansion, or rather, contraction of the mercury, from which, after having allowed for the expansion of the glass tube and the mercury in it, we deduced the absolute expansion of the vulcanite. The results of these experiments may be closely expressed in the following formula.

2.

$$V_t = V_0 + \cdot 000182t + \cdot 00000025t^2$$

The formula of the cubical expansion of mercury as given by Mendeleeff* is

$$V_t = V_0 + \cdot 0001801t + \cdot 00000002t^2$$

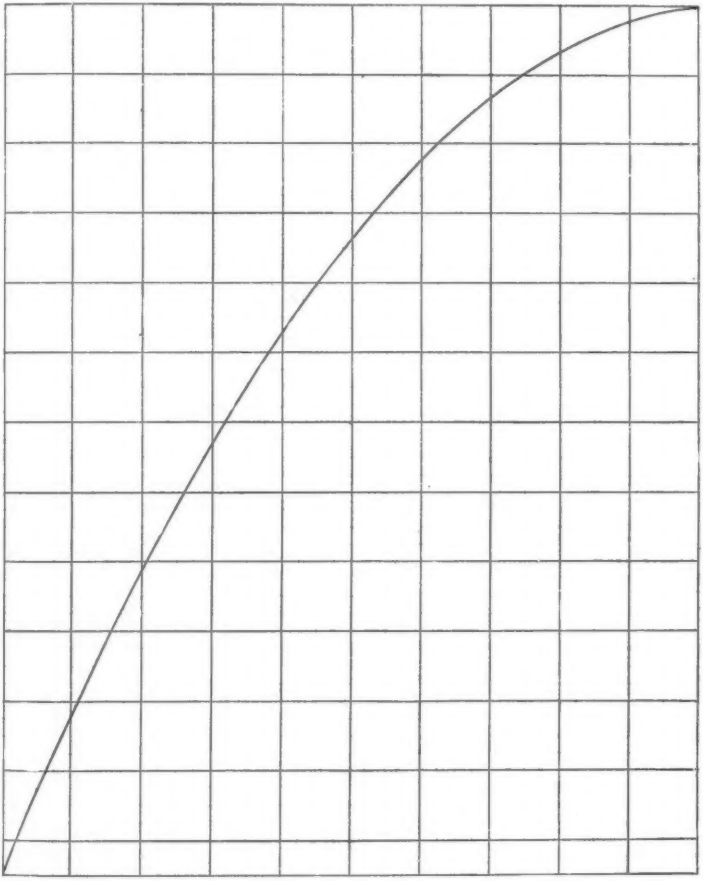
It is thus seen that the cubical expansion of vulcanite exceeds that of mercury so that the apparatus we have described may be used as a thermometer in which, as Kohlrausch observed, the scale will be inverted; when the temperature *rises*, the mercury in the stem *falls*.

The following table gives the volumes of vulcanite and of mercury at temperatures from 0° to 100°, as computed from the above formulæ. The difference, (in the fourth column),

*Jour. de Physique, v, p. 259.

which are all negative, show the increasing rate of expansion of the vulcanite over the mercury. These differences which form the apparent expansion (contraction) of the mercury in the ebonite thermometer are given in the accompanying curve, from which one may take the gradually increasing length of degrees on such a thermometric scale, which reads downward. The units of abscissæ, read from right to left, are 10° C., the units of ordinates, read downward, are each ·0002.

Fig. of Curve.



Temp.	Vol. of Mercury.	Vol. of Vulcanite.	Differences.
0°	1·000000	1·000000	·000000
10	1·001803	1·001845	·000042
20	1·003610	1·003740	·000130
30	1·005421	1·005685	·000264
40	1·007236	1·007680	·000444
50	1·009055	1·009725	·000670
60	1·010878	1·011820	·000942
70	1·012705	1·013965	·001260
80	1·014536	1·016160	·001624
90	1·016371	1·018405	·002034
100	1·018210	1·020700	·002490

As the apparent expansion of mercury in glass of a Fahr. thermometer is ·0000869 of its volume for 1°, and as the apparent contraction of mercury in a vulcanite thermometer is ·00249 from 32° to 212°, it follows that the length of scale from 32° to 212° on a vulcanite thermometer $= \frac{\cdot 00249}{\cdot 0000869} = 28°\cdot 6$ of length of scale on a similar mercurial thermometer of glass.

Kohlrausch states in his paper, cited above, that "the increase of the coefficient of expansion of ebonite with the temperature is very considerable. The linear expansion for the temperature t can be put

$$\cdot 000061 + \cdot 00000076\, t.$$"

This formula agrees well with that which we determined for the cubical expansion. Further on he says: "The solid expansion of ebonite is, from the above numbers, at 0° equal to that of mercury; at higher temperatures it is still greater. It is possible that other kinds expand still more, so that as a curiosity a mercurial thermometer might be constructed whose readings sink on being heated. "The great expansion may possibly be connected with the proportion of sulphur which ebonite contains: Kopp (Pogg. Ann., vol. lxxxvi. p. 156) found for the coefficient of sulphur ·000061 at 30°. On the other hand, the contrast to soft caoutchouc is very remarkable. I will mention one fact which was observed in the observation of expansion. The bar of ebonite, which was about one centimeter in thickness, after being heated required a considerable time before it assumed a constant length. Although the bad conductivity is doubtless the principal cause of this, I imagine that another phenomenon is also at work. Like the elastic change of form, the expansion by heat may also not take place instantaneously, but continue itself after the change of temperature, gradually becoming weaker. A few observations of Matthiessen's with glass (Pogg. Ann., cxxviii, p. 521), seem to

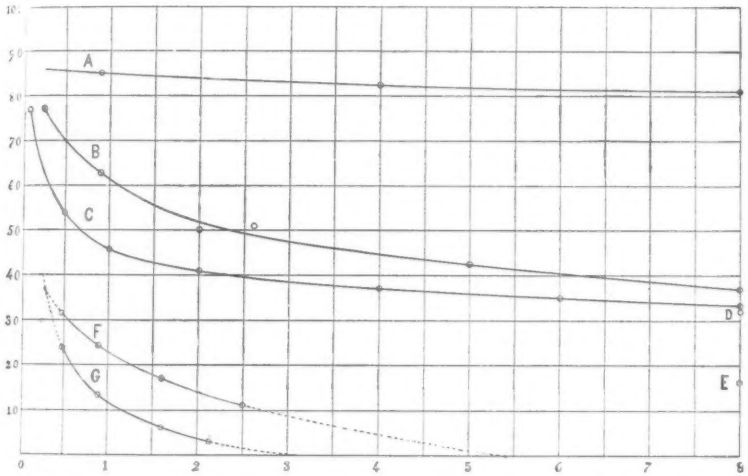
point in this direction; probably this thermal after action, like the elastic occurs in an eminent degree in organic substances."

The specific heat of vulcanite was determined by the method of mixtures. Small fragments of vulcanite were heated to near the temperature of boiling water in Regnault's apparatus and dropped into a water calorimeter. After corrections for equivalents in water of calorimeter and thermometer and for radiation and evaporation, three experiments gave these results:

1) ·33124 2) ·33077 3) ·33225 Mean = ·33125

On the diathermancy of vulcanite numerous careful experiments were made. The results of these and of experiments on other substances are given in the accompanying diagram of

4.



curves. In this diagram the figures on the axis of ordinates give percentages of heat effect on thermopile transmitted by plates of various substances whose thickness in millimeters is given by the figures on axis of abscissæ.

Curve A gives the heat effect of sun's rays transmitted by St. Gobain glass. The solar rays in these experiments and in those of F, G and E were reflected from a speculum-metal mirror of a heliostat.

Curve B shows the heat effect of rays from a Locatelli lamp transmitted by St. Gobain glass.

Curve C, the same as B as given by Melloni.

Curve F, the heat effect transmitted by sun's rays through vulcanite.

Curve G, the heat effect transmitted by sun's rays through vulcanite.

D is the percentage (32 per cent) of heat effect from a Locatelli lamp transmitted by a plate of obsidian 8^{mm} thick.

E is the percentage (16·5 per cent) of heat effect of sun's rays transmitted by a plate of obsidian 8^{mm} thick.

The examination of the curves F and G and of the points D and E shows that the rays transmitted by vulcanite and obsidian are of long wave-length; these are in greater percentage in the rays from the Locatelli lamp than in those from the sun. A plate of vulcanite one-half millimeter in thickness transmits 32 per cent of these rays while of the sun's rays 24 per cent are transmitted. The plate of obsidian of 8^{mm} thickness acts in like manner, but it screens even a greater proportion of the sun's rays than it does those from the Locatelli lamp.

In making the experiments on the transmission of the sun's rays I used a revolving diaphram pierced with holes of various diameters. The face of this diaphragm was exposed to the solar beam; sections of which, equal to the area of the different holes, were transmitted to the thermopile, which was placed at such distances from the diaphragm that the whole of the rays transmitted were included in the area of the face of the pile. The deflections of galvanometer produced by beams going through holes of different diameters are given below.

Diameter of hole.	Deflection.	Diameter of hole.	Deflection.
1) $1{\cdot}25^{mm}$	8·5	3) $4{\cdot}9^{mm}$	131·5
2) 3·4	63·0	4) 6·1	204·0

If the heat given to pile is as the area of the aperture, then the squares of the diameter of aperture divided by the deflections should equal a constant, as follows:

1) $\frac{1{\cdot}5625}{8{\cdot}5} = {\cdot}1838$ 3) $\frac{24{\cdot}01}{131{\cdot}5} = {\cdot}1826$

2) $\frac{11{\cdot}56}{63} = {\cdot}1835$ 4) $\frac{37{\cdot}21}{20{\cdot}4} = {\cdot}1824$

Mean = ·18305

I mention these experiments because they show that such a diaphragm may be of service to those who wish to obtain in succession definite amounts of heat from a solar beam.

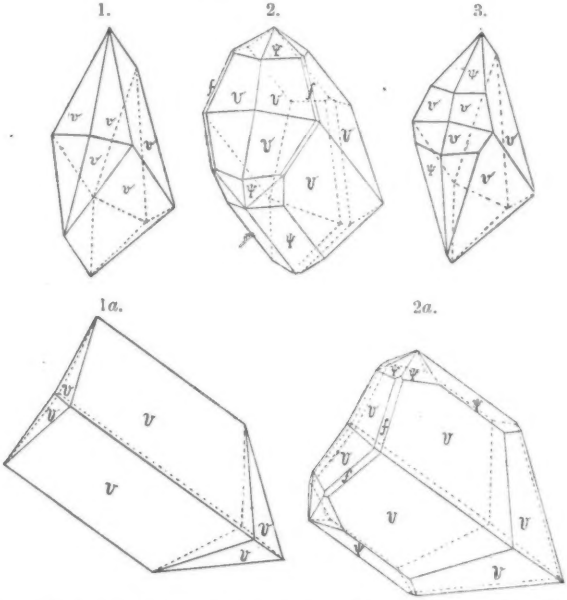
The index of refraction of vulcanite was measured by ascertaining, in a spectrometer, the angle of maximum polarization of a polished surface of vulcanite. The mean of fourteen measures gave for this angle 57° 29′, and the tan. 57° 29′ = 1·568 for the index of refraction; a number nearly as great as the index of refraction of flint glass.

Thin lenses of vulcanite and of obsidian were made for me by Mr. John A. Brashear and with them I concentrated the rays of long wave-length to invisible foci on the face of the thermopile.

Stevens Institute of Technology, Hoboken, N. J.

ART. IX.—*On some remarkably developed Calcite Crystals;* by LOUIS V. PIRSSON.

BEAUTIFUL specimens of calcite are procured at Guanajuato in Mexico, and through the dealers have found their way into collections. On these specimens, not only are simple scalenohedrons of the ordinary form, $1^3(21\bar{3}1)$, common, often of great beauty in the perfection of their crystal form, but also twins, which are often developed in a most remarkable manner. As these, so far as can be learned, have never been described, it has been thought that an account of them with some figures, would not be without interest.

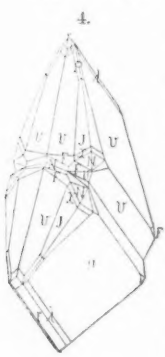


The twins consist in general of the ordinary 1^3 scalenohedron, twinned always upon $01\bar{1}2$, $-\frac{1}{2}$. By a development of two faces of the scalenohedron and the corresponding ones in twin position, the crystals are lengthened out into four sided prisms, with a re-entrant angle at one end and a salient angle at the other. They are usually attached to the rock at the salient angle with the prism projecting and at first sight present no appearance of hexagonal symmetry. They appear rather like twinned monoclinic crystals, consisting of a prism and pyramids, the latter forming the re-entrant angle at the end.

In fig. 1 the simplest and most common of these forms is shown; $v=1^3\ (21\bar{3}1)$. In this figure the crystal is drawn in the usual position of the plus scalenohedron; in fig. 1*a* the same crystal is shown after a revolution of 60° into the position of a minus scalenohedron in order to better present the great development of four of the scalenohedron faces into a prism. This is the usual development of the greater number of specimens examined. The prism like form varies greatly in length with different crystals. These twins and simple individuals occur intimately associated together on the same specimen. Some twins are very large, up to eight or ten inches long. The larger crystals are however of the simple twinned form described, while the smaller ones are in general more highly modified. One of these is shown in fig. 2 in its normal position and in fig. 2*a* revolved, as in the previous example, 60° to show its prismatic development. On this crystal the forms *v*, 1^3, $(21\bar{3}1)$; *W*, $\frac{1}{5}^{\frac{11}{3}}$, $(7\ 4\ \bar{1}\bar{1}\ 15)$; and *f*, $-2\ (02\bar{2}1)$ were observed.

The most common habit of the smaller crystals is shown, however, in fig. 3, where of the scalenohedron, $\frac{1}{5}^{\frac{11}{3}}$ one pair of faces is represented, largely developed in front, cutting off the main form 1^3 above the re-entrant angle, while the other two pairs are either wholly wanting or are developed in so small a degree as to practically be so. It will be observed in the study of these crystals that all scalenohedral faces which appear as bevelments of the acute prism-like edge, must lie in the zone $10\bar{1}1 \wedge 01\bar{1}2$ and this affords an important aid in their identification. The crystal faces do not generally reflect light well but sufficiently so for fair measurements on the reflecting goniometer and the determination of the forms.

Fig. 4 represents a very remarkable calcite from the collection of Mr. Norman Spang, who very generously presented it to Professor Penfield and the latter has kindly allowed me to study and figure it in connection with these Mexican crystals. Mr. Spang obtained it in the southwest, but the exact locality could not be discovered. From its general similarity to the described forms, it will be suspected of having come from the Mexican locality. It differs from all of them which have been examined in being much more highly modified and especially by the presence of minus forms. The forms observed on this crystal were *r*, 1, $(10\bar{1}1)$; *v*, 1^3, $(21\bar{3}1)$; *F*, 2^3, $(24\bar{6}1)$; *J* $-4^{\frac{7}{3}}$, $(8\ 20\ \bar{2}\bar{8}\ 9)$; *P*, -4^3, $(4\ 8\ \bar{1}\bar{2}\ 5)$; *x*, -2^3, $(13\bar{4}1)$; *N* $-4^{\frac{5}{3}}$ $(4\ 16\ \bar{2}\bar{0}\ 3)$, and *λ*, 1^3, $(31\bar{4}2)$.



While the planes of the plus forms were generally smooth and gave fair reflections of the signal, the minus forms were always striated, resulting from an oscillation of them with the main face $-4\frac{7}{3}$. These striations were not however, as is often the case, mere lines blending the signals into an unbroken band of light, but were distinct facets, often of some size. As a result, each form gave a distinct reflection of the signal, by which it was possible to recognize and measure it with a fair degree of accuracy. The form -4^3 occurred as a distinct pair of faces at the top of the striations and by covering the latter with wax, the former could easily be measured with exactness. The striations of these minus forms were also all in one zone and this when determined aided greatly in their identification. Along the zone, the signal of each face stood out sharply in a dim band of light connecting them and pretty exact measurements could be made. The forms -2^2 and $-4\frac{5}{3}$ occurred most largely at the bottom and they are so represented in ideal symmetry in the figure. At the re-entrant angle, the main plus form e, 1^3, and the main minus form $4\frac{7}{3}$, occurring in about equal development, the crystal presents at this end the appearance of the di-hexagonal pyramid.

The following table of measured and calculated angles is appended to show the identification of the forms.

Angles of Scalenohedrons.

		Long edge.			Short edge.			Middle edge.		
1^3 $(21\bar{3}1)$	calc.	35°	35½′	calc.	75°	22½′	calc.	132°	58′
	meas.	35	49	meas.	75	21	meas.	133	05
		36	10		75	07		133	07
1^2 $(31\bar{1}2)$	calc.	24	10				calc.	113	45
	meas.	24	13				meas.	113	26
								113	56
$\frac{11}{5}{}^3$ $(7\ 4\ \bar{11}\ 15)$	calc.	22	01	calc.	39	41			
	meas.	22	04	meas.	40	40			
		22	30						
2^3 $(24\bar{6}1)$	calc.	37	30						
	meas.	37	00						
$-\frac{4}{5}{}^3$ $(4\ 8\ \bar{12}\ 5)$	calc.	34	20½	calc.	72	22			
	meas.	34	20	meas.	72	23			
		34	10						
	calc.	30	11½	calc.	81	16½	calc.	131	30
$-4\frac{7}{3}$ $(8\ 20\ \bar{28}\ 9)$	meas.	30	01	meas.	81	02	meas.	131	29
		30	15		81	12		131	56
		30	11						
		30	18						
$-4\frac{5}{3}$ $(4\ 16\ \bar{20}\ 3)$	calc	21	29½						
	meas.	21	40						

And also the following angles:

		Calc.	Meas.		
$r \wedge v$	$10\bar{1}1 \wedge 12\bar{3}1$	29 01½	29° 01′	29°	29° 04′
$r \wedge r$	$10\bar{1}1 \wedge 0\bar{1}11$	74 55	74 58	75	75 03
$r \wedge \lambda$	$10\bar{1}1 \wedge 31\bar{4}2$	9° 25′	9 30	9 31′	9 35
$P \wedge x$	$(4\,8\,\bar{1}\bar{2}\,5 \wedge 13\bar{4}1)$	11 01½	10 50	11	11 19
$v \wedge P$	$(21\bar{3}1 \wedge 4\,8\,\bar{1}\bar{2}\,5)$	20 29	20 28	20 29	20 15
$v \wedge F$	$(21\bar{3}1 \wedge 24\bar{6}1)$	8 57	8 54		

In conclusion the author desires to express his thanks to Professor G. J. Brush, who kindly afforded the use of material from his collection and to Professor S. L. Penfield for valuable assistance and advice.

Mineralogical Laboratory,
Sheffield Scientific School, June, 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a Relation between Capillary Phenomena and Molecular Mass.*—Goldstein has experimented upon the rise of aqueous solutions in capillary tubes and finds that in all or nearly all of the cases examined, there is a distinct relation between the molecular mass of the dissolved salt and the height to which the column of liquid rises. In his experiments, he operated in two ways. In the first, solutions were employed of such strength that the heights to which they rose in the capillary tubes were the same. In the second, the concentration of the solutions was the same and the ascent in the tubes different. Thus for example operating with 17·776 per cent solutions of the following substances, the heights obtained were as follows:

Substance.	Molecular mass.	Height.
NaBr	103	73·9
$CaCl_2$	183	73·4
$BaCl_2$	208	72·5
CaI_2	366	69.4

In the same tube, which had a radius of 0·1833 millimeter, water rose to the height of $80{\cdot}57^{mm}$ at 22°. Since Mendeléeff has shown that the critical point of liquids can be calculated from the decrease of capillary height by changes of temperature, and since Schiff has observed a close relation between the boiling point of a liquid and its capillary constant, the author believes the laws of vapor pressures are the same as those governing the ascent of liquids in capillary tubes. The law of vapor pressure is represented by the expression $f-f'/f=kg$; in which f is the vapor pressure of the solvent, f' that of the solution, k a constant and g the mass of the dissolved substance. In like manner, Goldstein proposes the expression $H-h/HM=C$ to represent the capillary

phenomena, H representing the rise of water in the tube, h the rise of the solution, M the molecular mass of the dissolved substance and C a constant for the particular percentage of the salt used. Because salt-solutions do not follow the law of osmotic pressure, nor the laws of Wüllner and Raoult, the author multiplies the formula-values by Van't Hoff's coefficient i; and obtains for the final values of $10{,}000\,(H-h)i/HM$ the following numbers: NaCl 13·35, KCl 13·24, $MgCl_2$ 13·26, $CaCl_2$ 13·36, $SrCl_2$ 13·78, $BaCl_2$ 13·77, $CoCl_2$ 13·95, $CdCl_2$ 13·87. The same result appears when certain data obtained by Valson with a five per cent solution are used to calculate the constant from the above formula. This conclusion is in accord with that of Traube. —*Zeitschr. Physikal. Chem.*, v, 233, Apr., 1890. G. F. B.

2. *On a Relation between Heat of Fusion and Solubility.*—In consequence of the striking analogy between the osmotic pressure of dissolved substances and ordinary gaseous pressure, an analogy to which attention was first called by Van't Hoff, reasoning before applicable only to gaseous substances may now be applied to solutions. Walker has sought to combine the thermodynamical equation $D_T p = \rho/T_0$ with the gas equation $pv = 2T$, now applicable to solutions; and thus to deduce a relation between the solubility of a substance in a given solvent and its heat of fusion. The resulting differential equation $dp/p = \rho\, dT/2T^2$ gives by integration, after multiplying by T, the expression

$$T \log p = -\frac{\rho}{2} + \left(\log p_0 + \frac{\rho}{2T_0}\right)T.$$

In these formulas, T is the absolute temperature, p the osmotic pressure in the saturated solution, v the volume of the solution and ρ the molecular heat of solution, assumed constant. Plotting the above equation with the values of $T \log p$ as ordinates and T as abscissas a straight line is obtained, the constant factor $\log p_0 + \rho/2T_0$ being the tangent of the angle which the line makes with the axis of abscissas. This angle may be fixed by determining the solubility of the substance at two different temperatures; so that when one of these temperatures is the fusing point, the equation is

$$\rho = 2T_0(\tan \alpha - \log p_0).$$

A similar equation may be written for the fused substance, in which however, the molecular heat of fusion must be added to the heat of solution; so that the total heat is $\rho + \sigma$ and the new equation is

$$\rho + \sigma = 2T_0\ (\tan \alpha' - \log p_0).$$

Subtracting from this the former equation, we have

$$\sigma = 2T_0(\tan \alpha' - \tan \alpha)$$

by means of which σ or the molecular heat of fusion may be calculated. The straight line obtained by plotting the new equa-

tion T log $p' = -\frac{1}{2}(\rho+\sigma)+(\log p_0+(\rho+\sigma/2T_0))T$, cuts the former one at a point corresponding to the temperature of fusion. The author has calculated the heat of fusion of paratoluidine by this formula from its solubility in water and finds it to be 44·5 calories per gram, while the value directly determined is 39 calories. From the solubility of water in ether, he obtains for the heat of fusion of ice 154 calories; whereas it is in fact only 80. But this result is based on the assumption that the molecule of the dissolved water is H_2O; so that if it be H_4O_2, the calculated value will become 77, which not only agrees quite well, but is in accord with the statement of Eykman that only half the normal depression of the freezing point is observed when water is dissolved in liquid paratoluidine.—*Zeitschr. physikal. Chem.*, v, 193; *J. Chem. Soc.*, lviii, 686, July, 1890. G. F. B.

3. *On the Relation of Cupric chloride solutions to Heat.*—From thermo-dynamical considerations it follows, as Le Chatelier and Van't Hoff have pointed out, that when the heat of solution of a substance in its almost saturated solution is negative, the solubility will increase with rise of temperature; while when it is positive the reverse will be the case. REICHER and VAN DEVENTER have tested this conclusion for cupric chloride $CuCl_2.(H_2O)_2$; one of the few salts which dissolve in much water with evolution of heat, its temperature-coefficient of solubility being positive. Consequently a remarkable behavior should be observed with this salt with respect to the heat of solution in liquids of different concentration. The authors find as theory predicts, that in a saturated solution the heat of solution is negative. From thermochemical data given by Thomsen on the heat of dilution of solutions of cupric chloride joined to data of their own, the authors calculated that at 11° the heat of solution attains a maximum when the solvent has a strength of about 8 molecules of $CuCl_2.(H_2O)_2$ to 198 molecules of water. At this concentration, therefore, the salt would be dissolved without any thermal effect whatever; and this, experiment shows to be the fact. When the concentration is about 18 molecules of the salt to 198 molecules of water, the heat of solution becomes negative. *Zeitschr. physikal Chem.*, v, 559; *J. Chem. Soc.*, lviii, 1206, Nov., 1890. G. F. B.

4. *On the Heat of Combustion of Nitrogenous Animal Products.*—By means of the calorimetric bomb, BERTHELOT and ANDRÉ have determined the heat of combustion of the chief nitrogenous constituents of animal tissues, the results of which determinations are given in the following table. In this table column 1 gives the value in water-gram-degrees for one gram of the substance at constant pressure, column 2 the value for the quantity of material containing one gram of carbon, column 3 the heat of combustion of one gram if the nitrogen is eliminated in the form of urea and column 4 the value for the quantity containing one gram of carbon, the nitrogen being eliminated as urea.

	1.	2.	3.	4.
Albumin	5690	10991	4857	9381
Blood fibrin	5532	10820	4586	8970
Muscular flesh	5731	10671	4749	8841
Hæmoglobin	5915	10617	4964	8902
Casein	5629	11080	4799	9580
Ossein	5414	10806	4544	8976
Chondrin (calf)	5346	10544	4506	8924
Vitellin	5784	11166	4954	8596
Yolk of egg	8124	12052	7704	11632
Vegetable fibrin	5836	10807	4986	9047
Crude gluten	5995	10878	5245	9338
Isinglass	5242	10800	4192	8640
Fibroin	5097	10599	4077	8479
Wool	5567	11099	4537	9009
Chitin	4655	9943	4235	9043
Tunicin	4163	9014	4063	8794

In a second table given in the memoir, the percentage composition of these substances is given. It appears from the data given, therefore, that the average heat of combustion of the food-albuminoids is about 5691 calories per gram, or 10870 calories for the quantity which contains one gram of carbon. The loss of heat resulting from the elimination of nitrogen in the form of urea is 16 per cent. The mean heat of combustion of the carbohydrates is 9470 calories for the quantity containing one gram of carbon, the heat for one gram varying with the hydration. This heat is about one-fifth greater than that of the carbon present, this reserve of energy being the source of the heat developed during many fermentations. In the case of fats the heat of combustion per gram of carbon is from 12200 to 12500 calories owing to their small percentage of oxygen. About one-sixth of the total possible heat of the albuminoids is not available since the nitrogen is eliminated as urea; but in the fats and carbohydrates all the heat of combustion is available.

In another paper, Berthelot and André have given the heat of combustion for several nitrogenous compounds derived from the albuminoids; this heat being determined by combustion in oxygen in the calorimetric bomb. Glycollamine yields 3133·6 calories per gram, alanine 4370·7, leucine 6526·1, asparagine 3396·8, aspartic acid 2911·1, tyrosine 5915·9, and hippuric acid 5659·3. If the total heat of combustion be compared with the heat of combustion when the nitrogen is eliminated in the form of urea—conditions closely resembling those of the living organism—it will be observed that the heat is very much less in the second case; indicating the important part played by urea in connection with animal heat. If the nitrogen is eliminated in the form of uric acid, the deficit is 115200 calories per 14 grams, or 122000 calories if the carbon dioxide is in solution. If the nitrogen is eliminated as hippuric acid the deficit per 14 grams is 1012900 calories. In the herbivora, compensation occurs in the liberation of free nitrogen in the intestines and so the thermal deficit is small.—*C. R.*, cx, 884, 925; *J. Chem. Soc.*, lviii, 936, 937, September, 1890. G. F. B.

5. *On the Action of Zinc on dilute Sulphuric acid.*—The curious intervention of a third substance in chemical reactions has long been noticed. In the absence of moisture, for example, phosphorus may be distilled unchanged in oxygen and in the absence of nitrous acid nitric acid has no action upon either silver or copper. From this stand-point, PULLINGER has studied the action of zinc upon sulphuric acid. The zinc was purified by three distillations in vacuo, in a tube of hard glass. The acid was purified by diluting with three times its mass of water and boiling for six hours in a flask provided with an inverted condenser. A sphere of this zinc 1·25 grams in mass, lost in this acid of specific gravity 1·179 only five milligrams in sixty minutes. The conclusions of the paper are as follows: (1) Pure zinc with a perfectly smooth surface is not acted on by dilute sulphuric acid which has been submitted to prolonged boiling; (2) pure zinc with a rough surface is readily acted upon, but in a less degree by acids which have been boiled than by those which have not; (3) oxidizing agents such as electrolyzed sulphuric acid, hydrogen peroxide and nitric acid, increase the rate of solution; (4) reducing agents such as hydriodic acid almost entirely prevent solution, those containing sulphur however, like sulphurous oxide, being without effect; (5) it is not improbable that when zinc with a rough surface dissolves in dilute sulphuric acid, persulphuric acid acting by its presence is the cause of the solution; and (6) in all probability *pure* dilute sulphuric acid at ordinary temperatures would be entirely without action on metallic zinc whether the surface of the metal were rough or smooth.—*J. Chem. Soc.*, lvii, 815, Sept., 1890. G. F. B.

6. *New Melting-point Apparatus.*—An improved melting-point apparatus has been devised by CHRISTOMANOS, consisting of a two-necked bottle containing mercury, which can be heated in an air-bath. Through one of the openings a thermometer passes and also a wire from a voltaic cell. Through the other passes the drawn out end of a glass funnel. The substance to be experimented upon is placed in this funnel in the fused state and allowed to solidify. The space above it is then filled with mercury and the funnel is introduced into the bottle. The second wire from the battery connects, through a vibrating bell, with the mercury in the funnel. Upon raising the temperature of the bottle to the fusing point of the substance, contact is established between the two portions of mercury and the bell is made to ring. The temperature of the mercury in the bottle is then noted.—*Ber. Berl. Chem. Ges.*, xxiii, 1093, April, 1890.

G. F. B.

7. *Chemistry, Organic and Inorganic.* By Charles Loudon Bloxam. 7th Edition, revised and edited by John Millar Thomson and Arthur G. Bloxam. 8vo, pp. xii, 799, Phila., 1890. (Blakiston).—To the special features which have made Bloxam's chemistry so well known among chemists, the present edition adds new matter in the organic part, such as Raoult's method for

molecular mass, and the investigation of Fischer and Tafel on sugars. Portions of the book have been re-written and the whole has been revised so as to bring it up to date.

8. *Electro-chemical Analysis.* By Edgar F. Smith, Ph.D. 12mo, pp. 116. Philadelphia, 1890. (Blakiston).—Dr. Smith has done the science of analytical chemistry a real service by the preparation of this little book. Thanks largely to his own work in this direction, electrolytic methods of separation are rapidly coming into use in the laboratory and by their accuracy of result and convenience of application are gradually replacing purely chemical methods. The chemical student therefore will be glad to welcome a manual in which the theory and practice of electro-chemical quantitative analysis are so well set forth.

9. *Sugar Analysis.* By Ferdinand G. Wiechmann, Ph.D., 12mo, pp. viii, 187. New York, 1890. (Wiley).—The author's aim in preparing this book has been to meet the needs not only of the sugar house but also of the technical school. In a concise form he has collected together the principles and practice of the art of sugar analysis based on the use of the polariscope. The methods of sampling, the preparation of the material for examination, the optical analysis, with and without inversion, etc., are clearly described. The book closes with nineteen valuable tables, given to facilitate the necessary calculations.

10. *Practical Inorganic Chemistry.* By Ebenezer J. Cox, F.C.S. 16mo, pp. 51. London, 1890. (Percival & Co.).—This is a brief elementary class book designed to furnish the necessary notes, reactions and analytical tables required by the beginner in practical inorganic chemistry, in the Science and Art department.

11. *Velocity of Sound at very Low Temperatures.*—A base line of 1,279 metres was accurately measured, and the interval determined between the flash of a gun at one end and the appearance of the sound wave at the other. The following results were obtained: where t is the temperature, x the number of observations, and v the corresponding velocity:

$t =$	$-10°9$	$-25°7$	$-37°8$	$-45°6$
x	53·	114·	164·	205·
v	326·1	317·1	309·7	305·6m.

The velocity diminishes therefore 0·603 meter for 1° C.—*Phil. Mag.*, p. 507, Dec., 1890.

12. *Wave-lengths of Electrical Oscillations.*—In repeating Hertz's work upon this subject, H. K. Waitz has arrived at the following conclusions.

(1.) A discharge of an inductive coil of a definite species excites oscillations of different wave-length which may extend over an interval of many octaves.

(2.) Among these oscillations there is one of greater intensity, the wave-length of which is determined by the dimensions of the conductors.

(3.) The electrical oscillations in or upon conductors change

their wave-lengths when the medium surrounding the conductor changes.—*Ann. der Physik.*, No. 11, 1890, p. 435. J. T.

13. *Heat of the Moon and the Stars.*—C. V. Boys has used his radio-micrometer to detect the heat of the stars and the moon. Although the instrument was competent to detect the heat of a candle at a distance of 2·8 kilometers, an image of the brightest star produced by a silvered concave mirror of 16 inches aperture produced no sensible indication. The moon, however, gave large indications, and the author discusses the radiation from the moon by the method of curves. The radio-micrometer could detect $\frac{1}{150000}$ of the entire heat radiation from the moon.—*Proc. Roy. Soc. Lond.*, 47, p. 480–499, 1890. J. T.

14. *Foam.*—Lord Rayleigh in his investigation upon surface forces discusses the question of the formation of foam and concludes that a certain amount of impurity and want of cleanliness is necessary for the formation of foam. Foam cannot be formed in chemically clean substances. Calculation shows that the thickness of oil which is necessary to stop the movement of small pieces of camphor over a definite surface area of water amounts to only 1·5 millionths of a millimeter.—*Proc. Roy. Soc.*, 28, March, 1890. J. T.

15. *A photochronograph.*—M. Marey attaches to one end of a long band or ribbon of sensitive film a band of black opaque paper and to the other end of this film a similar band of red paper. The film is then rolled upon a bobbin beginning with the end of the red band. This operation is conducted in the dark room. The bobbin can afterwards be taken into the light, being fully protected by the black and red bands of paper. When one wishes to take a number of photographs of a rapidly moving object, the bobbin is introduced into the photographic apparatus. One end of the band rolls upon an empty bobbin and at the end of the operation the film is protected by the band of red paper. While the portion that is not exposed to the light is still covered with the black band, one can thus readily distinguish between the portions of the bobbin that have been exposed to light. The apparatus makes it possible to take a number of images upon the same band and consequently to submit them all at once to the same developer.—*Comptes Rendus*, Nov. 2, 1890, p. 626. J. T.

16. *Photographic Sensitives.*—H. W. Vogel discusses the question of the different sensitiveness of plate sensitized with eosine and erythrosine according to different methods. A solution of erythrosine in water shows an absorption band near E. A more concentrated solution gives a band fading into the blue. The addition of silver causes these bands to disappear and in their place appears between E and D a weaker band. These absorption bands are so decided that they afford a very sensitive means of deciding whether one is employing an eosine or a eosine silver plate.—*Beiblätter Ann. der Physik*, No. 10, 1890, p. 983. J. T.

II. Geology and Natural History.

1. *International Congress of Geologists.* — The Organizing Committee of the International Congress of Geologists met at the Institute of Technology in Boston, November 13th, 1890. Messrs. Chamberlin, Davis, Gilbert, Hall, Hague, Hitchcock, Powell, Newberry, Shaler, Stevenson, Winchell and Williams were present.

The Secretary reported the vote of the London Bureau regarding the change of place from Philadelphia to Washington. Thirty-six ballots were received, of these thirty-three were in favor of Washington. These represent the members from Great Britain, France, Germany, Australia, Austria, Belgium, Hungary, India, Italy, Portugal, Roumania, Russia, and the United States. No negative votes were received from countries outside America. The majority of the Bureau, as well as a majority of the American Committee, thus expressing their preference for Washington, it was voted to hold the next session of the International Congress of Geologists in Washington, during the week beginning with the last Wednesday (26th) of August next.

The vacancy in the Committee caused by the death of Mr. C. A. Ashburner, was filled by the election of Mr. S. F. Emmons, Washington, D. C. The Committee now consists of the following members: Messrs. Branner, Chamberlin, Cope, Dana, Dutton, Davis, Emmons, Frazer, Gilbert, Hall, Hague, Heilprin, Hitchcock, Sterry Hunt, Leidy, Lesley, LeConte, Marsh, Newberry, Powell, Proctor, Shaler, Stevenson, A. Winchell, Walcott, Whitfield, and H. S. Williams.

During this meeting vacancies were filled and the organization of the committee perfected, so that the present officers and sub-committees are as follows: *Chairman*, J. S. Newberry, New York City, *Vice-Chairman*, G. K. Gilbert, Washington, D. C.; *Secretaries*, H. S. Williams, Ithaca, N. Y., S. F. Emmons; *Acting Treasurer*, S. F. Emmons, Washington, D. C.

(1) A sub-committee on the *Scientific Programme:* J. W. Powell, *Chairman*, Washington, D. C., J. D. Dana, New Haven, Conn., T. C. Chamberlin, Madison, Wis.

(2) A sub-committee on *Longer Excursions:* Clarence Dutton, *Chairman*, Washington, D. C., N. S. Shaler, Cambridge, Mass., J. J. Stevenson, New York City.

(3) A nominating sub-committee to nominate officers for the Congress: J. J. Stevenson, *Chairman*, New York City, T. C. Chamberlin, Madison, Wis., Alex. Winchell, Ann Arbor, Mich.

The following resolutions were adopted:

That the secretaries be authorized to prepare a circular of information, stating the organization, the time of meeting, and such other information regarding the Congress as may be thought necessary, in English and in French, to be signed by the Chairman and the Secretaries, and distributed among those likely to be interested in this country and in foreign countries.

It was further *Resolved*, that the Secretary be authorized to communicate to the editors of the American Geologist and the American Journal of Science the results accomplished by the Committee at the present meeting.

And it was *Resolved*, that the Committee assess its members five dollars each for expenses.

2. (1) *New Types of Carboniferous Cockroaches from the Carboniferous Deposits of the United States;* (2) *New Carboniferous Myriapoda from Illinois;* (3) *Illustrations of the Carboniferous Arachnida of North America, of the orders Anthracomarti and Pedipalpi;* (4) *The Insects of the Triassic beds at Fairplay, Colorado;* by SAMUEL H. SCUDDER, Mem. Boston Soc. Nat. Hist., vol. iv, No. ix, pp. 401–472, pl. xxxi–xlii, September, 1890. —Few departments of paleontology have fallen so wholly into the hands of a single investigator as the American fossil arachnids, myriapods, and insects. The labors of Meek, Worthen, Dana and Dawson, from 1860 to 1865, really introduced the subject of the terrestrial arthropods in this country, and since that time Professor Scudder has been nearly the sole inquirer.

The present memoir is a continuation of previous descriptive papers, and adds a number of new and important species to the mylacridæ and myriapods, with a summation of the known American paleozoic species of the latter group. The portion treating of the Carboniferous arachnids contains descriptions, discussions and good figures of the Anthracomarti and Pedipalpi. The last paper of this memoir on Triassic insects of Colorado, possesses considerable geological interest. According to the author, it is the first attempt to determine the age of a series of beds from insect remains alone. From a study of the associated plants, the horizon was first referred to the Permian, but Professor Scudder has noted so many Mesozoic characters in the insect fauna that any other time reference would be incongruous. Similar paleontological contradictions have been encountered several times before, between the plants, invertebrates, and vertebrates, with the general result that the higher organisms are taken as the chronological standard. C. E. B.

3. *Bulletin from the Laboratories of Natural History of the State University of Iowa*, vol. ii, No. I, pp. 1–98, pl. x–xii, 1890. —The monograph of the Pselaphidæ of North America by Brendel and Wickham is brought to a completion, and also the memoir by Shimek on the Lœss and its fossils. Mr. Shimek concludes that during the formation of these deposits the summers were comparatively warm and the glaciers had retreated far to the north. The sedimentation was apparently at or near the surface, and produced through the agencies of numerous shallow ponds and sluggish streams, thereby accounting for the fineness of the material, the differences of level, and the preservation of extremely delicate land and freshwater mollusca with numerous local faunal differences. C. E. B.

4. I. *Ueber einige Lycopodiaceen aus der Steinkohlenformation;* II. *Die Graptolithen des K. Mineralogischen Museums in Dresden;* by Dr. H. B. GEINITZ.—Reports K. Min. Geol. u. Præ-hist. Mus. in Dresden. No. 9, pp. 1–33, with 3 plates, 1890. —A large species of *Halonia* (*H. Dittmarschi* Gn.) is described with notes and citations of other related forms. The second part besides being an account of a special collection, contains much valuable synonomy and a plate illustrating the principal species.

5. *Prodromus Faunæ Mediterraneæ sive Descriptio Animalium Maris Mediterranei incolarum, etc.;* by J. V. CARUS, vol. ii, pars ii, pp. 278–496. Stutgart, 1890.—This portion of the work finishes the Gastropoda, including the Heteropoda and Pteropoda. The whole of the Cephalopoda are described, and the Tunicata are carried nearly to completion.

6. *Minerals from Snake Hill, New Jersey.*—E. W. PERRY announces that he has found the following named minerals at Snake Hill, N. J., within the past three years: datolite, pectolite, laumontite, prehnite, apophyllite, natrolite, analcite, gmelinite, stilbite, heulandite, calcite. Of these the gmelinite and pectolite are in fine specimens, the former rivaling the Nova Scotia mineral. Snake Hill is an ejection of trap, surrounded by sandstone forming a distinct hill about 5 miles from Bergen Hill.

7. *The Silva of North America, by Professor* C. S. SARGENT, *illustrated from drawings by* C. E. FAXON.—Part I of this beautiful work appeared some weeks ago, being a folio of 120 pages, with 50 lithographic plates. The set is to be completed in twelve similar volumes, and will deservedly receive a place among botanical works of the very highest rank. While the care, accuracy, and breadth of experience, which are manifested in the descriptions, will render the *Silva* of great value to the professional botanist, the author has so skillfully avoided every unnecessary technicality of language that the text may be readily understood by any intelligent though unbotanical reader. The aim of the work is to give full descriptions and detailed illustrations of all trees, native or naturalized in North America, exclusive of Mexico. Although a number of works have been written on our North American forest trees, nearly all are at present long out of date, and each has been confined either to a limited area of the continent, or to definite groups in the botanical system. Nothing of so general a nature has yet appeared, and the present work supplies a long-felt need.

In a brief preface we learn something of the years of study which Professor Sargent has devoted to preparation for this gigantic undertaking. To insure greater accuracy, he has spared no endeavor to see in a living state every plant described, and in this has succeeded with surprisingly few exceptions. In the systematic arrangement of the orders and genera, Bentham and Hooker's *Genera Plantarum* has in general been followed. In the nomenclature adopted, the rules of priority have been scru-

pulously regarded. This involves in some cases changes which are certainly unfortunate, but are, as the author justly remarks, necessary, if anything like permanency in botanical nomenclature is ever to be reached. An instance of this is the discarding of the appropriate and well-established name *Magnolia grandiflora* for the less agreeable *M. foetida.* The volume before us contains descriptions of thirty-four species of trees, each illustrated by one or more plates showing foliage, flowers, and fruit. There is a very simple introductory key to the thirteen orders which are treated. The generic and specific descriptions are very full, and are enlivened by the introduction of many interesting facts regarding the habits, uses, medical properties, history, and even paleophytology of the trees described. We can hardly speak in too high terms of the plates. In conjunction with delicate outlining, Mr. Faxon has made frequent use of faint surface shading, a method rather unusual in botanic drawings, but here employed with remarkable success. The plates were lithographed in Paris under the direction of the noted botanical artist, M. Riocreux, and reflect much credit upon all who have engaged in their production. It is only to be regretted that a work of such merit is necessarily expensive, and can be possessed by comparatively few. On this account botanical institutions and reference libraries should, wherever possible, place the *Silva* within reach of students and readers. B. L. R.

8. *Recherches anatomiques sur les hybrides;* by M. MARCEL BRANDZA. (*Revue générale de botanique*, II, Nos. 22–23.)—The study of vegetable hybrids has heretofore been directed almost exclusively to their external characters, and to such of their qualities as appear to be of agricultural or horticultural importance. Some interesting points in their physiology have of course received attention, such for instance as the diminished fertility; and scattered references to their anatomy could undoubtedly be found. The article before us, however, represents the first attempt to subject a number of hybrids to extended anatomical investigation, with a view to discover the principles upon which the parent characters are combined in their tissues. The examples described are from the genera *Rosa*, *Sorbus*, *Marrubium*, *Medicago*, *Cornus*, and *Cirsium.* The author reaches the conclusion that in some hybrids the tissues show a juxtaposition, but not a mingling of particular characteristics of the parents. Thus in the stem of "*Marrubium Vaillantii*," a supposed hybrid of *Marrubium vulgare* and *Leonurus Cardiaca*, the arrangement of the collenchyma is closely like that of *Marrubium vulgare*, while the fibro-vascular bundles correspond in number and position to those of *Leonurus*, the parents differing conspicuously from each other in both tissues. In other hybrids the tissues possess in all characters an intermediate nature between the parents, as in *Medicago falcato-sativa.* In a third less satisfactory category of hybrids, of which the author gives *Cirsium arvense-lanceolatum* as an example, the tissues of some organs show the intermediate

nature, while in other parts of the plant a juxtaposition of special characters of the different parents may be detected.

While these are just the results which the morphological traits of hybrids would lead one to expect, they lose none of their interest on that account, and furthermore M. Brandza's studies leave no doubt that anatomical investigation can render important assistance to systematic botany in furnishing excellent collateral evidence in cases of puzzling and doubtful hybrids. B. L. R.

III. Astronomy.

1. *Catalogue of Radiant Points of Shooting Stars.*—In the Monthly Notices of the Royal Astronomical Society [vol. l, No. 7] Mr. Denning has given some of the results of his indefatigable observing during the last fourteen years. His observations were undertaken to ascertain the radiant points of the minor star-showers generally. He presents a catalogue of nine hundred and eighteen radiant points arranged according to date through the year. At the end of the paper is a list of 45 long enduring and apparently stationary radiant points of shooting stars. The individual observations of the meteors are not given, the number (9177) registered in the 1297¾ hours of observation furnishing an obvious reason.

The mean horary number of meteors seen was 8·3, but the number obtained from observations at Ashley Down, in the country, was 11·4, as compared with 8·2 in Bristol. The difference Mr. Denning attributes to the lights and smoke of the town.

From thirty-eight shooting stars doubly observed he obtained the average height at beginning 71·1 miles, and at end 48·2 miles. By a comparison of a large number of similar results obtained by others he deduced the average height of 683 meteors at beginning to be 76·4 miles, and of 756 meteors at end to be 50·8 miles. If fire-balls and shooting stars were taken separately he found the usual heights of fire-balls at disappearance to have been 30 miles, and of shooting stars to have been 54 miles.

The maximum number during the hours of the night were seen between 2 and 3 A. M., when the rate was about double that observed during the early evening hours. The observations were apparently made in the absence of the moon, and allowance was made in stating the hours of observing for time occupied in registering the observed tracks.

The mean hourly rate for the first six months of the year is 5·8 meteors, and for the last six months is 10·8.

The existence of radiants continuing unchanged for several weeks, and even months has been frequently asserted by Mr. Denning, and is here reaffirmed as a fact of observation. Such radiants are so at variance with received theories of meteors that evidence of their existence needs to be of more than usual positiveness in order to be accepted as conclusive. It is proper then to note that it is not the radiant itself that Mr. Denning

observed. He has given us his deductions from his observations, and not the observations themselves, for the place of a radiant cannot be directly observed. He should not be surprised if other persons do not therefore at once accept his important deductions as fully proven, and that they are waiting for additional evidence.

2. *Washington Observations for 1885*, Appendix I. Government Printing Office.—The report of Lieut. Winterhalter, who was sent to attend the astro-photographic congress in Paris, and to visit certain European observatories, constitutes the Appendix I to the volume of Observations of the U. S. N. Observatory for 1885.

3. *List of Observatories and Astronomers;* by A. LANCASTER. (3d ed.) Brussels, 1890.—In this third edition of Mr. Lancaster's exceedingly useful book, the position of the observatories and the names of the astronomers in the observatories are corrected to date. Special pains were taken by Mr. Lancaster to secure the most reliable data for the geographical positions.

4. *Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac*, vol. iv, Washington, 1890.—Mr. HILL gives in this volume his new theory of Jupiter and Saturn, the labor upon which has covered a period of seven and a half years. The method of Hansen is the basis of the development by Mr. Hill, but the modifications of that method to meet the demands of the problem are very considerable, so that the expression "a new theory" is entirely appropriate.

5. *Publications of the Washburn Observatory;* vol. vi, parts 1 and 2. Madison, Wis., 1890.—Part 1 of this volume contains the meridian observations made by Miss Lamb and Mr. Updegraff in 1887. The second part contains observations of double stars made by the director of the observatory, Mr. G. C. Comstock. The observations were made with the fifteen and a half inch equatorial during the years 1887–9.

6. *Terrestrial Magnetism.*—In Bulletin No. 18, of the U. S. Expedition to West Africa, Prof. F. H. BIGELOW gives a summary of some preliminary results reached in an investigation of the variations of the elements of Terrestrial Magnetism, undertaken in connection with his work on the Solar Corona (see this Journal, Nov., 1890, p. 393). After alluding to the inadequacy of present theories to explain the facts observed, he adds that one cause of vital importance has been omitted from the elements of the problem, namely, the motion of the Earth as referred to the ether in its neighborhood, and he proposes to base an explanation of Terrestrial Magnetism upon the dynamic effects produced by the inductive action of the Earth in its motions of rotation and translation through fields of force. In a word, the Earth may be regarded as a cosmical dynamo. Whatever may be the real nature of the ether, it possesses the property of transmitting directed influences according to the laws of energy, which may be regarded as vector potentials of various types. But two of these directed fields of

force at the Earth are considered, both generated by the Sun, one of which may be called the radiant field and the other the coronal field. The radiant field is propagated in rectilinear lines, and has been ordinarily discussed as phenomena of the æther, called heat and light; hence its direction towards the Earth is in the plane of the ecliptic. A sympathetic study of the electro-magnetic theory of light, and the recent discoveries in electrical oscillations, naturally leads one to a belief in this view, which is here assumed. The coronal field has been shown by the author to be formed by the same forces that are exhibited in the Solar Corona, of which it is the invisible extension; hence, the second premise is that the coronal field is directed perpendicularly to the ecliptic in the neighborhood of the Earth. It may be shown that the relative intensities of these two fields can be discovered by a consideration of the observed movements of the magnetic needle.

The solution of the problem depends upon ascertaining the mutual action, at any station, of the distribution of magnetism referred to three poles, the permanent pole, the rotation pole, and the translation pole, the names being assigned from important characteristics. These poles change their relations in diurnal, annual, and secular periods, depending upon known astronomical laws; thus *the permanent* pole, or the pole of the permanent magnetism of the Earth in the same hemisphere as the station, wanders in a secular period of long duration in the Earth's crust, and also rotates daily about the Earth's axis. The *rotation* pole, or the pole of induced magnetism, resulting from the earth's rotation, is an instantaneous pole formed successively by induction, its direction being a few degrees from the Sun, and lying near the plane of the ecliptic. The *translation* pole, or the pole of magnetic induction, formed by the motion of the Earth in its orbit, lies nearly along the line of the orbit as it pierces the Earth, and is also instantaneous.

After a discussion of the mathematical analysis required to solve the problem, particularly as to the position of the three poles, the composition of the fields, etc., the author goes on to say that a complete study of this problem will lead to the formation of equations of condition from observations, which, when solved, will give completely the unknown quantities, namely, the constants employed and the forces of the two cosmical fields. These being obtained, we can return to the problems of solar physics with renewed data. Hence, the magnetic needle on the earth's surface will probably be added to the spectroscope, the polariscope, and the bolometer, as an instrument for studying the constitution of the sun.

Some conclusions drawn are thus stated: *Long periods.*—The variations of the intensity of action in the sun cause corresponding fluctuations in the fields of force, detected as the 56-year, the 11-year, or other periods; if sporadic, as terrestrial magnetic storms. Since the poles of the corona do not coincide with the axis of rotation of the sun, the coronal field of

force is made to assume variable relations to the earth in direction and intensity, which gives rise to the 26-day period. *Annual.*—The variation of the components of the fields of force, combined with the change of position of the three poles among themselves, and the velocity of the earth in its orbit, produces the annual period, also simultaneously appropriate to both hemispheres. *Diurnal.*—The position of any observing station is constant as referred to the permanent pole, and both the station and this pole glide past the two instantaneous poles each day, producing the diurnal eastward and westward elongations in the position of the needle.

The distribution of the elongations.—The two instantaneous poles are located in such positions as to confine the active movements of the needle to the morning, forenoon, and early afternoon hours, leaving it nearly quiescent during the night. The afternoon elongation occurs at any station during the same hour throughout the year, as the comparatively steady position of the rotation pole requires. The two morning elongations, which fluctuate through two or three hours, follow the change of position of the translation pole as it moves eastward and westward through an angle of 45°. The principal neutral line, occurring an hour or more before noon, is coincident with the retardation of phase of the rotation pole. That there should be three sharply-marked elongations, and one undefined in time, agrees with the composition of the forces emanating from one quadrant of the Earth.

The latitudes.—Near the rotation pole the distribution of potential is at a maximum, which diminishes by a function depending upon the angular distance from it; near the translation pole it is at a minimum, and increases with an approach to the permanent poles. The polar latitudes of the Earth therefore feel especially the influence of the translation pole, and have a single, strong maximum and minimum; the middle latitudes are subject to both the polar distributions; the equatorial latitudes come at one time under a northern and again under a southern resultant of component actions.

The opposite elongations of the North and South Hemispheres.—The north permanent pole is surrounded by a magnetic force of one name, and the southern pole by a force of the other name; the rotation pole and the translation pole have but one kind of magnetism about each of them, whether these forces are of the same sign or not, which, reaching over into the Northern and the Southern Hemispheres, simultaneously produce opposite motions of the respective needles.

The disturbances.—The magnetic inductive forces can be traced within the surface of the solid earth by laws similar to those employed in discussing the inductions within the atmosphere; and there is every reason to believe that these currents, in conjunction with the free electricity deposited in the atmosphere as an associated function, due to the air being an heterogeneous conductor,

and not changing all the magnetic forces into heat through natural decay, will go far to explain the phenomena of the spasmodic disturbances.

The aurora.—The atmosphere screens off only a part of the components resolved parallel to the earth's axis, so that we have a field of lines of induction which may be again resolved parallel to the axis of the permanent magnetism of the earth. The effect of these conditions is to gather up such lines of force around the poles, and they may produce a system of relations like those seen in the aurora. A test can be applied by measuring whether in inclination the upper parts of the auroral beams are bent more rapidly towards the poles than the theoretic lines of force produced under the laws of the magnetic potential will admit.

IV. Miscellaneous Scientific Intelligence.

1. *Mexican Meteorites.*—Mr. Fletcher of the British Museum has made and published in the Mineralogical Magazine an exhaustive study of the numerous Mexican meteoric irons. He has collected the original accounts relating to the numerous irons that have been brought from Mexico. The following are his conclusions respecting the dispersion of these iron masses over the several Mexican States:

"In each of the States of Zacatecas, Oaxaca and Guerrero, only a single mass of meteoric iron has been found, and there is absolutely nothing to suggest that they do not represent independent falls.

"In Sinaloa, likewise, only a single mass has been met with, and its characters have not been determined: a suggestion of a relationship with another group would rest on the slight fact that the site of an extremely large mass is in a straight line with two other sites where large masses are now lying.

"In San Luis Potosi two localities are recognized, but there is a strong probability that the Charcas mass, which has undoubtedly been transported to that town from a distance, was brought from the neighbourhood of Catorce: and, even if this was not the case, there is no evidence that the mineralogical characters are such as to render separate falls improbable.

"In Durango four or five distinct localities are known, but the characters of the only masses which have been examined point unmistakably to the falls of distant masses having been independent of each other.

"In Mexico there has undoubtedly been a large shower of limited dispersion in the Valley of Toluca: the three remaining masses from Mexico and Morelos have not been examined, and are very small and portable: even if they have not been transported, they may be found on examination to present characters which will differentiate them from the masses of the Toluca shower.

"From Coahuila many masses have been got, but it is extremely probable that all of them were brought from a single district of very small area: the two Nuevo Leon masses have never been examined and had obviously been transported, perhaps from Coahuila or San Luis Potosi.

"In Chihuahua three or four areas are represented: but of the masses found in that State only those of the Huejuquilla group have been examined, and that in a very incomplete way: the recognition of the singleness of the fall of the Huejuquilla group depends almost entirely on the general similarity of appearance of the large masses. If the masses really belong to a single fall, as the available information makes most probable, the maximum dispersion is now 66 miles: but one of the terminal masses, that of San Gregorio, is known to have been transported by the Spaniards on one occasion for 1½ leagues, while according to a tradition current three centuries ago it had accompanied the Indians when they journeyed southward to take possession of that part of Mexico."

2. *Kilauea.*—A letter from Rev. E. P. Baker of Hilo, dated Nov. 5th, speaks of Dana Lake, or a lake occupying essentially its position west of the debris-cone in Halemaumau, as boiling violently all over its surface, so that no crust remains upon it. Jets consisting of successive clots of melted lava from three feet to six, ten and even twenty feet in height were in constant play over it. He had not seen the lake lava so hot at any time during the past ten years.

Mr. Maby, at the Volcano House, about two months previous had reported that on Sept. 9th all activity in Dana Lake ceased, and that there was an outbreak of lava in another place. But three days later, the lake was again active and four other spots in its vicinity had opened.

3. *University Studies;* Published by the University of Nebraska.—This third number of a new and important series consists of three papers: 1st, The determination of specific heat and of latent heat of vaporization with the vapor calorimeter, by H. N. Allen. 2d. The color vocabulary of children, by H. K. Wolfe. 3d. The development of the King's Peace and the English local Peace-Magistracy, by G. E. Howard.

4. *Gesammelte Mathematische Abhandlungen;* von H. A. SCHWARZ.—The very important Mathematical Contributions of Professor Schwarz during the past thirty years, have been republished in two handsome octavo volumes by Julius Springer of Berlin. The first of these volumes is devoted entirely to his discussions of surfaces of minimum extent. The second volume contains his various papers in Geometry, differential equations, and other branches of the Higher Analysis.

APPENDIX.

ART. X.—*A Horned Artiodactyle* (Protoceras celer) *from the Miocene;* by O. C. MARSH.

IT is an interesting fact, that while all existing mammals with horns in pairs are artiodactyles, and none of the recent perissodactyles are thus provided, the reverse of this was true among the early forms of these groups. The *Dinocerata* of the Eocene, a specialized order of ungulates, as well as some of the perissodactyles of both the Eocene and Miocene, had horns in pairs, while no horned artiodactyles have hitherto been known from either the Eocene or Miocene.

A fortunate discovery made during the past season, in the Miocene of South Dakota, proves, however, that before the close of this period, one artiodactyle, at least, was provided with a pair of horns. This animal was apparently a true ruminant, and nearly as large as a sheep. Only a single skull is known, and this, fortunately, is in good preservation, except the extremity in front, which is broken off and lost. In general form and proportions, this skull is of the ruminant type. Its most striking feature is a pair of small horn-cores, situated, not on the frontals, but, on the parietals, immediately behind the frontal suture. These prominences were thus placed directly over the cerebral hemispheres of the brain.

The frontal bones are very rugose on their upper surface, and this rugosity extends backward on the parietals, and to the summit of the horn-cores, as well as between the latter, and along the wide sagittal crest. The horn-cores are well separated from each other, and point upward, outward, and backward, overhanging somewhat the temporal fossæ. They are conical in form, with obtuse summits.

Between the orbits, the frontals are depressed, and marked by two deep grooves leading backward to the supra-orbital foramina. Behind these, halfway to the horn-cores, is a median prominence resembling in shape the corresponding elevation on the skull of the male giraffe. The brain cavity is unusually large for a Miocene mammal. The occiput is very narrow, indicating a small cerebellum, and the occipital crest is weak. The occipital surface slopes backward.

The facial region of the skull is narrow and elongate. On the outer surface of the maxillary, just above the antorbital foramen, there is a deep depression, which probably contained a gland. The usual ruminant fossa in front of the orbit appears to be wanting. The orbit is large, and completely closed behind by a strong bar of bone.

The dentition preserved is selenodont and brachyodont, with only three premolars and three molars. The first premolar is much compressed transversely, and has but a slight inner lobe. The second premolar is triangular in outline, the inner lobe being much more developed. The last premolar has this lobe expanded into a strong cusp, and the crown thus becomes broader than long. The true molars have two inner cusps, each with a basal ridge. The outer crescents have a median vertical ridge. The enamel of the molar series is more or less rugose. There was a wide diastema in front of the premolars.

The posterior nares are situated far forward, the anterior border being opposite to the posterior cusp of the second true molar. The glenoid facet is large and convex, but the post-glenoid process is quite small. The paroccipital processes were well developed, but there were apparently no auditory bullæ.

This skull when entire was about eight inches (200^{mm}) in length. The distance between the orbits across the frontals is about three inches (75^{mm}), and the distance between the summits of the horn-cores, about one and one-quarter inches (32^{mm}). The extent of the premolar and molar series is three and one-eighth inches (80^{mm}), and the width of the palate between the true molars is one and one-quarter inches (32^{mm}).

As the animal represented by this skull is very distinct from any hitherto described, the genus may be named *Protoceras*, in allusion to the early appearance of horns in this group. The species may be termed *Protoceras celer*. The characters now known suggest affinities with the giraffes, but indicate a distinct family, which may be called the *Protoceratidæ*.

The geological horizon is in the upper part of the Oreodon beds of the Miocene. For securing this important specimen, the writer is indebted to his able assistant, Mr. J. B. Hatcher, whose many discoveries in the West are well known.

New Haven, Conn., December 17, 1890.